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THE MINERAL CHARACTERISTICS THAT AFFECT METAL RECOVERIES FROM THE Cu, Zn, Pb AND Ag ORES FROM MANITOBA.

PART 4.

A MINERALOGICAL EVALUATION OF THE BEHAVIOUR OF METALLIC MINERALS IN THE STALL LAKE CONCENTRATOR CIRCUIT.

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ABSTRACT

Samples of the feed, concentrates and tailings from the Stall Lake concentrator circuit were taken on April 18th 1989. The samples were assayed for 8 elements, and image analysis was done to determine the modal quantities, host particle size distributions, liberations and associations of the minerals. Material balances were done to simulate the behaviour, and to determine the recovery of metals, minerals, and of free and unliberated grains of the valuable minerals in the end products.

The feed assayed 2.39 % Cu, 2.50 % Zn, 1.60 ppm Au and 14.1 ppm Ag. Although 91.4 % of the Cu and 77.3 % of the Ag, only 56.4 % of the Au is recovered in the Cu-concentrate. The Cu-concentrate grades 3.90 % Zn, accounting for 15.2 % of the Zn in the feed. Furthermore, only 51.9 % of the Zn is recovered in the Zn-concentrate, with 33.0 % lost to the tailings. The feed contained (in vol%) 45.7 % gangue, 32.3 % pyrite, 7.94 % pyrrhotite, 6.86 % chalcopyrite, 4.37 % sphalerite, 0.30 % galena and 0.11 % arsenopyrite. Trace amounts of tetrahedrite, stannite, gudmundite, boulangerite, cassiterite and altaite were also observed.

Of the chalcopyrite in the feed 87.8 % occurs as 'recoverable' grains, of which approximately 93.1 % are recovered in the Cu-concentrate. Furthermore, 77.5 % of the middling grains, but only 17.7 % of the sub-middling grains are recovered in the Cu-concentrate; 78.5 % are rejected to the tailings. Approximately 60 % of the chalcopyrite in the tailings occurs as sub-middling grains, and corresponds to approximately 5 % of the chalcopyrite in the feed. The losses of sub-middling and middling grains are only recoverable through extremely fine regrinding. Regrinding will also address the minor 'over-sized' sub-free grains rejected to the tailings.

Of the sphalerite in the feed 87.1 % occurs as 'recoverable' grains, of which approximately 58 % are recovered in the Zn-concentrate, 12 % in the Cu-concentrate, and 30 % are rejected to the tailings. The loss of approximately 12 % of the 'recoverable' grains to the Cu-concentrate, corresponds to 9.5 % of the sphalerite in the feed, and accounts for 62 % of the sphalerite in the Cu-concentrate. These losses are due to poor selective flotation, possibly related to improper conditioning, and are not amenable to regrinding. Sphalerite losses to the tailings are as middling (6 %), sub-middling (16 %), but principally as 'recoverable' (78 %) grains. The losses of 'recoverable' grains to the tailings are due to poor flotation and circuit efficiency in the recovery of grains that fall largely within 'recoverable' particle liberation and size limits. Thus, approximately 73 % of the sphalerite lost to the Cu-concentrate and tailings combined occurs as 'recoverable' grains; not amenable to regrinding. However, the remaining 27 % of the lost sphalerite, accounting for approximately 13 % of the sphalerite in the feed, is potentially amenable to extremely fine regrinding, and improved recovery. Fine regrinding may increase chalcopyrite and sphalerite liberation and recovery by as much as approximately 6 and 10 %, respectively.

The probable principal hosts of Ag are chalcopyrite, pyrite, tetrahedrite, sphalerite and galena. No Au-bearing mineral was observed.

INTRODUCTION

A mineralogical study was conducted on mill products (i.e. concentrator slurry samples) from the Stall Lake concentrator circuit as part of a project within the CANADA-MANITOBA MINERAL DEVELOPMENT AGREEMENT. This project entitled "The mineralogical characteristics that affect metal recoveries from the Cu, Zn, Pb and Ag ores from Manitoba" was conducted as a contract to Hudson Bay Mining and Smelting Co. Ltd. (HBM&S) from CANMET, Dept. of Energy, Mines and Resources, under the supervision of the CANMET Scientific Authority Dr. W. Petruk. The work was performed by the author at the University of Manitoba as an employee of HBM&S under this contract.

The objective of the project was to establish whether the volcanogenic massive sulphide deposits of Manitoba contain unique mineralogical characteritics, and to determine whether these characteristics can be utilized to modify metallurgical practises, so that recovery could be optimised. Mineralogical studies on the ores from the Trout Lake deposit, and mill products from the Trout Lake concentrator circuit in Flin Flon comprised Parts 1 and 2 of the project. Part 1 sought to define the mineralogical characteristics that could have a bearing on mining and mineral processing (Healy & Petruk 1988), whereas Part 2 evaluated the behaviour of the minerals in the concentrator circuit (Healy & Petruk 1989a). Part 3 evaluated the behaviour of minerals in the HBMS concentrator circuit (Healy & Petruk 1989b).

Part 4 of the project involved sampling the feed, concentrates and tailings of the Stall Lake concentrator circuit, which is housed in the HBM&S Snow Lake concentrator. Sieve size, chemical, petrographic and image analysis was done on each of the four products. The image analysis included modal, grain size, mineral liberation and mineral association analysis. Material balance calculations were done on several of these analytical data, to determine the behaviour and inter-relationships of the metals and minerals through the circuit.

METHODS OF INVESTIGATION

SAMPLING

Sampling was done by HBM&S staff at Snow Lake on April 18th 1989, and submitted to the author after splits were sieved and chemically analyzed. Exceptionally high Zn head grades were encountered during the sampling campaign, and these probably influenced the high Zn losses to the tailings.

CHEMICAL ANALYSIS

The four samples were analysed chemically for Cu, Zn, Au, Ag, Cd, Pb, Fe, S and Sb at the HBM&S assay laboratory, Flin Flon., The dried samples required no preparation for chemical analysis, as they are fine-grained and homogeneous. The HBM&S assay laboratory have previously achieved a relatively high degree of accuracy and precision (Healy & Petruk 1988, 1989a), hence no reference ore standards were included with this batch of samples.

SIEVE SIZE ANALYSIS

The four samples were submitted to HBM&S for sieve size analysis. The samples were machine sieved, using stacked Tyler Series meshes with the mesh numbers 48, 65, 100, 150, 200 and 325. The weight of retained material in each sieve, and that passing 325 mesh was determined and recorded for each sample. The feed was ground to 57.7 % - 325 mesh.

PETROGRAPHIC AND IMAGE ANALYSIS

The four samples were prepared as polished sections at CANMET, Ottawa. Approximately 200 mg of the sample was mounted in epoxy/araldite in such a manner as to minimize fractionation of the sample by gravity settling of the particles. The polished sections were petrographically examined in preparation for image analysis. During petrographic and image analysis of the polished sections, thirteen ore minerals[1] were observed, and confirmed by EDA (See Table 4). The petrographic examination qualitatively determined the abundance, median grain size, degree of liberation, and the type of locked species of the minerals of interest. This information was useful in constructing an appropriate image analysis routine.

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[1] Ore minerals are informally defined here as minerals characteristic of the ore zone, but are not necessarily of economic value e.g. sulfides, alloys, sulfosalts, selenides, tellurides, etc.

The image analysis was done at CANMET, Ottawa on the MP-SEM-IPS image analysis system, which was developed by Petruk (Petruk 1987). The SEM capabilities of the Jeol 733 electron microprobe, the image producing component of the system, permit the generation of high resolution backscattered electron (BSE) images of the polished sample surface. The BSE (or grey level) image of a single field of the sample surface is tranferred to the Kontron SEM-IPS image analyser and digitized. Those areas of the image detected within the grey level window of each mineral are transformed into separate binary images. These mineral-specific binary images are stored in the image memory assigned to each mineral or mineral group (i.e. gangue[2] or pyrite + marcasite). At this point the various stereological measurements are made, and the procedure is repeated for successive fields. For further details of the specific technique used, see Healy & Petruk (1987, 1988, 1989a) and Petruk (1988a, 1988b).

The mineral quantitites were determined by measuring the relative areal fraction of each mineral (or group), and these were normalized to area % or volume %. Grains of the mineral(s) of interest were also described on the basis of their host particle size distribution, degree of liberation (i.e. classification) and degree of association with other minerals in composite particles. Due to a technical oversight when formulating the image analysis routine, the host particle diameter, and not the consitituent grain diameter was determined. However, the host particle and grain size are essentially equivalent for free and sub-free grains (See below), which are the dominant liberation categories of chalcopyrite and sphalerite in the Stall Lake circuit products. The host particle sizes of chalcopyrite, sphalerite, galena and pyrite were determined by measuring the surface areas of the host particles of the respective minerals, and using the square root of the area as the diameter. This 'equivalent square diameter' (or 'equivalent edge length of a square') gives sizes that compare closely with sieve size analyses (Petruk 1978).

The degree of liberation is measured using a classification, which describes the degree to which each particle containing a grain of the mineral of interest is locked with other minerals. The grains are classified into a four-fold classification based on the grains contribution in terms of volume % to the total volume of the particle, and hence the expected flotation characteristics of the particle. The 'free' grains are defined as comprising 99.9 to 100 % of the particle. The 'sub-free' particles are those in which the grain comprises between 99.9 % and 70 % of the particle, and which is expected to behave essentially as if free, i.e. in accordance with the flotation characteristics of the mineral of interest. The 'middling' particles are those in which the grain comprises 69.9 % to 30 % of the particle, and whose flotation characteristics are likely to mimic that of either the mineral of interest or the accompanying mineral(s). The 'sub-middling' particles are those in which the grain comprises less than 29.9 % of the particle, and whose flotation characteristics are expected to correspond to that of the dominant accompanying mineral(s).

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[2] Gangue is informally defined here as non-sulfide minerals characteristic of the surrounding hostrocks, and of no economic value i.e. silicates, carbonates and phosphates.

The mineral associations of the mineral(s) of interest were determined by measuring the relative surface area of the mineral of interest (e.g. chalcopyrite) that is in contact with another specified mineral (e.g. sphalerite). The associations are further classified on the basis of whether the mineral of interest occurs in the host particle along with just the other specified mineral (i.e. binary), or with the specified mineral and others (i.e. ternary).

Image analysis of the polished sections for each product was done using program PRGM #529, which uses a magnification of x150 (pixel size = 1.012 um) over an analytical area of approximately 40 to 120 fields per sample. The following parameters were determined (1) quantities of each mineral (or mineral group); (2) host particle size distributions and liberations (i.e. classification) of chalcopyrite, sphalerite, pyrite and galena; and (3) mineral associations of chalcopyrite, sphalerite and galena occurring in binary and ternary particles. No stereological corrections were applied to the data.

MATERIAL BALANCE CALCULATIONS

In order to evaluate plant performance and accurately describe the steady-state operation of an ore processing circuit using quantitative measurements of selected process variables (e.g. chemical assays, or mineral liberations) from different streams in the circuit, it is necessary to do material balance calculations (Laguitton & Wilson 1979). The weight of the products are unknown, and the raw analytical data contains sampling, sample preparation and analytical errors. Thus, material balance calculations are used to generate a new set of coherent data. The material balance calculations of this study were done using the MATBAL program, which uses a 'least squares refinement' technique to itteratively adjust the raw data, and produces 'best fit' or 'balanced' values.

The weight or flow rate of each stream is determined with the MATBAL program using chemical assays as the most precise process variables available. The stream flow rates were determined with the MATBAL program using the chemical assays for Cu, Zn, Fe and S. Only minor adjustments in other variables were generated when material balance simulation of these process variables (e.g. mineral quantities and liberation data for sphalerite and chalcopyrite) were based on these initial flow rates. Cross-balancing errors were also minor, indicating that the data are relatively globally coherent for different process variables. The accepted flow rates are 9.724, 2.542 and 87.734 for the Cu-concentrate, Zn-concentrate and tailings, respectively.

Having determined the stream flow rates for each product, these were than fixed, and other process variables were balanced by MATBAL to give adjusted values of these variables. The MATBAL program simultaneously calculated the recoveries of each variable in each product. Material balances were done on several types of data in order to determine the recoveries of metals, minerals, specific categories of free and/or

unliberated grains, and of particles with specific associations of mineral pairs or ternary combinations. These data types are: (1) chemical assays; (2) modal quantities data for all minerals of interest; (3) modal data for free chalcopyrite sphalerite, pyrite and galena; (4) modal data for categories of free plus unliberated chalcopyrite, sphalerite, pyrite and galena; and (5) mineral association data for chalcopyrite and sphalerite.

Both the chemical assay and modal quantities data were material balanced by entering the raw data directly into the MATBAL program. However, the mineral liberation and association data can only be material balanced after it is weighted in terms of the amount of the mineral(s) of interest present in each product. This is achieved by determining the modal fractions of the Cu and Zn assay in each product that occur in the specific liberation categories of the corresponding mineral to be material balanced (i.e. free, unliberated, sub-free, middling and sub-middling). This is based on the assumption that the Cu and Zn assays are more precise modal equivalent of the chalcopyrite and sphalerite abundances. However, the minor undetermined fraction of the Zn assay due to the Zn-spinel gahnite ($ZnAl_2O_4$) degrades the linear relationship between the Zn assays and sphalerite modal quantities. Thus, for example, modal fraction of the Cu assay, but not of chalcopyrite, occurring as free grains of chalcopyrite was material balanced. The modal fraction of the Cu assay occurring as free grains in each product are then material balanced. The % liberation (i.e. % free) is the percent of the adjusted Cu assay accounted for by the adjusted modal fraction of the Cu assay that occurs as free chalcopyrite for a given product. Thus, a set of adjusted liberations are not generated by MATBAL, but are extracted from two sets of internally, but not necessarily globally, coherent data. Importantly MATBAL balances each set of process variables independently, such that the adjusted data may not cross-balance. However, ideally the closer the true values are approached for each variable, the closer the cross-balance achieved.

CHEMICAL ANALYSIS

The four samples were chemically analysed for 8 elements, and the assays are presented in Table 1. The samples are ordered for presentation starting with the feed, the Cu-concentrate, Zn-concentrate, and the tailings. This format will be consistently used throughout the report.

Three analyses for Sb were below the detection limits of 0.01 wt%, and thus the Sb data are not considered further. The remaining 7 elements gave concentrations for all samples above their respective detection limits. The assays were adjusted by material balance calculations in order to model the steady-state operation of the circuit in terms of the assays. The adjusted assays and the calculated weights of each product are presented in Table 2. The recovery of the 8 elements in each of the end products was calculated simultaneously from these adjusted assays and are presented in Table 3.

The adjusted head grades are 2.39 % Cu, 2.50 % Zn, 1.60 ppm Au and 14.1 ppm Ag, which contrasts strongly with the 1985 budgeted grades for Stall Lake ore of 4.03 % Cu, 0.31 % Zn, 1.41 ppm Au and 5.83 ppm Ag (Barlin 1986). The Stall Lake ore has been traditionally processed in a separate circuit from the Chisel Lake ore, because of conflicting metallurgy i.e. Stall Lake ore is high Cu, low Zn, and Chisel Lake ore is high Zn, low Cu. Thus, the head grades of this study are anomalously Cu poor and Zn and Ag rich, and this probably contributed to some of the

TABLE 1

RAW ASSAYS FOR THE FOUR STALL LAKE CIRCUIT END PRODUCTS.

PRODUCT	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)	Sb (wt%)
Feed	1.41	14.8	2.39	2.50	28.2	24.9	0.09	nd.
Cu-Conc.	10.3	108.	22.5	3.90	32.0	33.6	0.18	0.02
Zn-Conc.	1.03	18.2	0.81	51.0	12.6	33.2	0.70	nd.
Tails.	0.82	3.09	0.21	0.94	28.0	23.1	0.06	nd.

metallurgical problems identified in this study.

The Cu-concentrate, which has a product weight of 9.724, grades 22.5 % Cu and 3.90 % Zn. The Cu grade lies within the normal range of grades (i.e. 20 to 28 % Cu), and constitutes 65 % of the ideal maximum obtainable grade of 34.5 % Cu, and an enrichment ratio of only 9.4. The

TABLE 2

ADJUSTED ASSAYS FOR THE FOUR STALL LAKE CIRCUIT END PRODUCTS.

PRODUCT	PRODUCT WEIGHT.	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)
Feed	100.0	1.60	14.1	2.39	2.50	28.1	24.6	0.09
Cu-Conc.	9.724	9.28	112.	22.5	3.90	32.0	33.7	0.18
Zn-Conc.	2.542	1.03	18.2	0.81	51.0	12.6	33.2	0.70
Tails.	87.73	0.77	3.11	0.21	0.94	28.1	23.3	0.06

TABLE 3

ELEMENT RECOVERIES IN THE FOUR STALL LAKE CIRCUIT END PRODUCTS.

PRODUCT	PRODUCT WEIGHT.	Au (ppm)	Ag (ppm)	Cu (wt%)	Zn (wt%)	Fe (wt%)	S (wt%)	Pb (wt%)
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	9.724	56.4	77.3	91.4	15.2	11.1	13.3	19.8
Zn-Conc.	2.542	1.63	3.29	0.86	51.9	1.14	3.43	20.2
Tails.	87.73	42.0	19.4	7.70	33.0	87.8	83.3	60.0

3.90 % Zn grade represents a substantial loss of Zn to the Cu-concentrate, which is one of the primary focuses of this study, and which is a historical and ongoing metallurgical problem in the processing of Flin Flon-Snow Lake ores.

The Zn-concentrate, which has a product weight of 2.542, grades 51.0 % Zn and 0.81 % Cu. The Zn grade constitutes 85 % of the ideal maximum obtainable grade of 59.8 % Zn, based on the Zn-content of Stall Lake sphalerite (Wiggins & Craig 1980), and an enrichment ratio of 20.4. The 0.81 % Cu grade of the Zn-concentrate is low compared to that of the Trout Lake Zn-concentrate (i.e. 1.67 % Cu; See Healy & Petruk 1989a), and well within acceptable limits.

The tailings, which has a product weight of 87.73, grades 0.21 % Cu, 0.94 % Zn, 3.11 ppm Ag and 0.77 ppm Au. Although each of these grades represent significant losses, those of Zn and Au are unacceptably high (Table 3).

The elements are divided into three groups on the basis of their distribution in the four end products (Table 3).

Group 1 consists of Cu, Ag and Au, which display high recoveries in the Cu-concentrate with minor recoveries (i.e. < 5 %) in the Zn-concentrate, but with significant losses (i.e. 7.7 to 42 %) to the tailings. The recovery of 91.4 % of the Cu to the Cu-concentrate is comparable to that at Trout Lake (i.e. 91.7 %; See Healy & Petruk 1989a), and reflects excellent recovery of chalcopyrite in the Cu-circuit. However, the relatively high loss of 7.70 % of the Cu to the tailings indicates some lattitude for possible process improvement. The recovery of 77.3 % of the Ag in the Cu-concentrate is exceptionally high compared to 48.5 % in the Trout Lake Cu-concentrate (Healy & Petruk 1989a) and 61.3 % in the HBMS Cu-concentrate (Healy & Petruk 1989b). This is in part attributable to the markedly minor losses of 3.29 % to the Zn-concentrate, which indicates that sphalerite is host to a maximum of only 6.5 % of the Ag in the ore. The moderate losses of 19.4 % of the Ag to the tailings is likely partly accounted for by Ag in solid solution in the unrecovered chalcopyrite and sphalerite, but principally in pyrite. The recovery of 56.4 % of the Au in the Cu-concentrate is relatively typical of Flin Flon-Snow Lake ores, whereas the minor recovery of 1.63 % to the Zn-concentrate is exceptionally low, and the recovery of 42.0 % to the tailings is exceptionally high. As no Au-bearing minerals were observed, a definite statement on the behaviour of Au is impossible. However, it may be inferred that the much of the Au losses to the tailings probably occur as 'invisible' Au in pyrite and arsenopyrite.

Group 2 consists of Zn only, which is recovered principally in the Zn-concentrate with significant losses (i.e. < 33 %) to the Cu-concentrate and tailings. However, the recovery of only 51.9 % of the Zn in the Zn-concentrate and the corresponding loss of 33 % of the Zn to the tailings are anomalously poor, while the 15.2 % loss to the Cu-concentrate is close to the upper limit, but nonetheless within the normal range, of such losses recorded in Flin Flon-Snow Lake Cu-concentrates. Contributing to the Zn grade in the feed and the high Zn losses to the tailings is an undetermined fraction of the Zn assay that occurs as gahnite, which has an average Zn-content of 33.0 % Zn (calculated from data of Trembath 1986). However, the fraction of the Zn assay in the feed occurring in this trace to minor mineral, and which is metallurgically unrecoverable, is probably minor (i.e. < 5 %). Thus, as will be shown later, the bulk of the Zn losses to the tailings are potentially amenable to routine recovery. However, these high losses may be largely due to the high Zn-grade and consequent operation of the Zn-circuit above normal capacity, and thus may not be indicative of routinely poor circuit preformance. The 15.2 % loss to the Cu-concentrate, which is a primary focus of this study, represents a common, mineralogically defined, largely liberation-independent, yet seemingly intractable metallurgical problem for Flin Flon-Snow Lake Cu-circuits.

Group 3 consists of Fe, S and Pb, which display high recoveries to the tailings, and low to moderate recoveries in the Cu- and Zn-concentrates. These distributions reflect the essentially inert flotation behaviour of the principal host minerals pyrite, pyrrhotite, Fe-bearing silicate gangue and galena. The somewhat higher recovery of Pb in the Cu-concentrate (i.e. 19.8 %) and Zn-concentrate (i.e. 20.2 %) largely reflects unliberated grains of galena locked with chalcopyrite and sphalerite, respectively, rather than free grains, as galena is essentially inert to flotation with Minerec (Healy & Petruk 1989a).

MINERAL QUANTITIES ANALYSIS AND MINERAL BALANCES

This section describes the evaluation of the modal quantities of the principal ore minerals (See Table 4) in the four end products. Mineral quantities were determined by image analysis system as described in the PETROGRAPHIC AND IMAGE ANALYSIS. This involved measuring the relative areal fraction of minerals within the polished section. The data are presented in the stereologically equivalent units of volume %.

The mineral quantities of gangue, pyrite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite and galena were determined. Minor marcasite and magnetite contribute to the pyrite mineral quantities. Determination of the modal quantities of the trace minerals tetrahedrite, stannite, cassiterite (See Plate 1A), gudmundite (See Plate 1B), boulangerite (See Plate 1B) and altaite (See Plate 1C) were not undertaken. No Au-bearing minerals were observed in the product samples during the course of this study.

MATERIAL BALANCES OF THE MINERAL QUANTITIES

The raw modal analyses for the four end product are presented in Table 5. and these were adjusted by material balance calculations in order to simulate their behaviour through the circuit under the steady state conditions. The adjusted mineral quantities are given in Table 6, while the calculated recoveries are given in Table 7. It is apparent by comparing Tables 5 and 6 that the adjustments to the raw data are relatively minor for all minerals. Also shown in Table 6, under the column entitled 'Total' is the sum of these adjusted mineral quantities for each product. It is apparent that there is a minor cross-balancing deficit in all products. The magnitude of this systematic error (i.e. < 3 %) is within acceptable limits.

The calculated Cu assays derived from the adjusted mineral quantities of chalcopyrite are 2.55 % Cu in the feed, 22.9 % Cu in the Cu-concentrate, 0.66 % Cu in the Zn-concentrate, and 0.19 % Cu in the tailings. These compare favourably with the adjusted Cu assays of 2.39 % Cu, 22.5 % Cu, 0.81 % Cu, and 0.21 % Cu in the respective products. The calculated Zn assays derived from the adjusted mineral quantities of sphalerite are 2.79 % Zn in the feed, 3.66 % Zn in the Cu-concentrate, 49.3 % Zn in the Zn-concentrate, and 1.18 % Zn in the tailings. These compare satisfactorily with the adjusted Zn assays of 2.50 % Zn, 3.90 % Zn, 51.0 % Zn, and 0.94 % Zn in the respective products. The data indicates reasonable agreement of the chemical and mineral quantities analyses. This is especially true in view of the small amount of, and the potential for fractionating, the material examined by image analysis compared to chemical analysis.

The minerals can be placed in four groups on the basis of their distribution in the four end products (Table 7), and these are described below.

TABLE 4

ORE MINERALS OBSERVED IN THE STALL LAKE END PRODUCTS.

NAME	FORMULA	ABUNDANCE
SULFIDES.		
Pyrite	FeS_2	Major.
Chalcopyrite	$CuFeS_2$	Major.
Sphalerite	ZnS	Major.
Pyrrhotite	$Fe_{(1-x)}S$	Major.
Marcasite	FeS_2	Minor/Trace.
Galena	PbS	Minor/Trace.
SULFARSENIDES		
Arsenopyrite	$FeAsS$	Minor/Trace.
OXIDES.		
Magnetite	Fe_3O_4	Major/Minor.
Cassiterite	SnO_2	Trace.
SULFOSALTS.		
Tetrahedrite	$(Cu,Ag)_{10}(Fe,Zn)_2(Sb,As)_4S_{13}$	Trace.
Stannite	Cu_2FeSnS_4	Trace.
Boulangerite	Pb_5SbS_{11}	Trace.
SULFANTIMONIDES		
Gudmundite	$FeSbS$	Trace.
TELLURIDES.		
Altaite	$PbTe$	Trace.

Presented in order of decreasing abundance of the mineral groups, and of the minerals in each group.

TABLE 5

RAW MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (vol%)	Sphal.	Asp.	Gal.
Feed	43.7	38.6	6.80	6.71	3.39	0.101	0.639
Cu-Conc.	10.3	7.39	7.57	68.2	6.15	0.104	0.310
Zn-Conc.	1.16	1.46	11.1	1.86	83.9	0.000	0.564
Tails.	53.6	33.1	10.1	0.49	2.09	0.390	0.242

TABLE 6

ADJUSTED MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (vol%)	Sphal.	Asp.	Gal.	Total.
Feed	45.7	32.3	7.94	6.86	4.37	0.109	0.296	97.74
Cu-Conc.	10.3	7.41	7.43	65.6	6.18	0.103	0.318	97.29
Zn-Conc.	1.16	1.46	11.0	1.86	85.4	0.010	0.571	99.06
Tails.	50.9	35.9	7.90	0.49	1.82	0.112	0.285	97.66

TABLE 7

RECOVERY OF THE MINERALS OF INTEREST IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy. (%)	Sphal.	Asp.	Gal.
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	2.19	2.23	9.11	93.1	13.7	9.23	10.5
Zn-Conc.	0.07	0.12	3.53	0.69	49.7	0.23	4.91
Tails.	97.8	97.7	87.4	6.26	36.6	90.5	84.6

Group 1 consists of gangue and pyrite, both of which behave as essentially inert minerals, with greater than 97 % rejected to the tailings, and with essentially identical minor recoveries in the Cu-concentrate (i.e. 2.2 %) and the Zn-concentrate (i.e. 0.10 %).

Group 2 consists of pyrrhotite, arsenopyrite and galena, all of which are heavily rejected (i.e. > 85 %) to the tailings, but with minor recoveries in the Cu-concentrates (i.e. 9 to 10 %) and Zn-concentrate (i.e. < 5 %). The higher recovery of these minerals to the Cu- rather than Zn-concentrate merely reflects the lower grade of the Cu-concentrate, resulting in the recovery of composite particles containing grains of these minerals, as well as the recovery of free grains. The observation of numerous free grains of these minerals in the Cu- and Zn-concentrates shows that these minerals are not entirely inert during flotation.

Group 3 consists of chalcopyrite only, which readily floats into the Cu-concentrate with very high recoveries (i.e. 93.1%). Chalcopyrite shows low recovery (i.e. 0.69 %) in the Zn-concentrate, with the bulk of the rejected chalcopyrite (i.e. 6.26 %) being lost to the tailings. The disparity between the recovery values for chalcopyrite and those for Cu are not significant, and are within the uncertainty of the analyses. The recovery of 93.1 % of the chalcopyrite constitutes excellent recovery, though the loss of 6.26 % of the chalcopyrite to the tailings indicates some lattitude for improved recovery, depending on its liberation characteristics. The loss of minor chalcopyrite to the Zn-concentrate (i.e. 0.69 %) is well within routine and acceptable limits of such losses, and is not significant.

Group 4 consists of sphalerite only, of which only 46.7 % is recovered in the Zn-concentrate, with unacceptably high losses of 13.7 % to the Cu-concentrate and 36.6 % to the tailings. The substantial loss of 13.7 % of the sphalerite to the Cu-concentrate, prior to the Zn-circuit, is in part due to the recovery of free grains, as well as unliberated grains of sphalerite. Petrographic examination revealed that the sphalerite losses to the tailings are largely as medium-grained free and sub-free grains. Thus, substantial losses of liberated sphalerite to the Cu-concentrate and tailings are indicated, and suggest that significant improvement in Zn recovery is attainable through improved rejection of 'recoverable' sphalerite in the Cu-circuit, and optimizing recovery of 'recoverable' sphalerite in the Zn-circuit.

PLATE 1

PLATE 1.

(A) TAILINGS : Grain of cassiterite (Cst) containing a rounded inclusion of sphalerite (Sp). Pyrite (Py) comprises bulk of sulfides in the tailings. Backscattered electron (BSE).

(B) FEED : Composite particle consisting of boulangerite (Boul) and lesser gudmundite (Gud). BSE.

(C) FEED : Single grain of altaite (Alt), with chalcopyrite (Cp), sphalerite and pyrite. BSE.

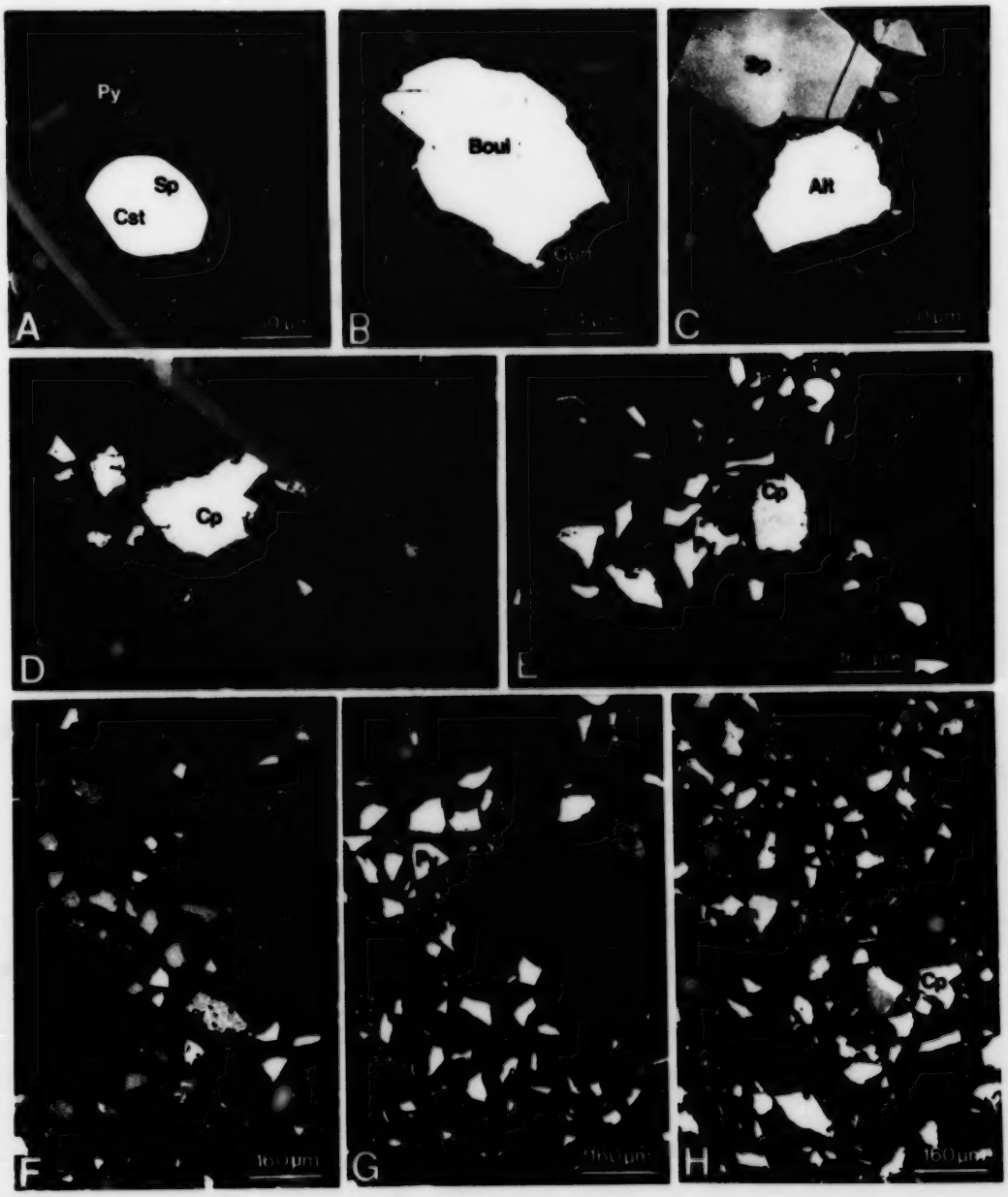
(D) Zn-CONCENTRATE : Common medium- and coarse-grained ('over-sized') chalcopyrite, with only minor chalcopyrite locked with sphalerite. Note only one grain of pyrite in field. Plane Polarized Light (PPL).

(E) TAILINGS : 'Over-sized' grain of sub-free chalcopyrite containing sub-middling diablastic sphalerite. Note two free grains of sphalerite (i.e. a and b). Dominant sulfide phase is pyrite. PPL.

(F) Zn-CONCENTRATE : Common medium-grained free chalcopyrite grains and granular and diablastic middling and sub-middling chalcopyrite locked with sphalerite. PPL.

(G) TAILINGS : Coarse- and medium-grained free and sub-free grains of sphalerite (i.e. a to d) rejected to the tailings. Dominant sulfide phase is pyrite. PPL.

(H) Cu-CONCENTRATE : Coarse- to fine-grained free and unliberated grains of sphalerite. Note much of sphalerite and pyrite is locked with chalcopyrite. PPL.


Py
Sp
Cst
A
Boul
B
Sp
Alt
C
Cp
D
Cp
E
F
G
Cp
H
160 µm

MINERAL LIBERATIONS AND ASSOCIATIONS

In this section the liberation, classification and association of chalcopyrite, and sphalerite, and the liberation data of galena and pyrite in the circuit products are evaluated. The liberation (% free) is the relative volume % of each mineral of interest that occurs as free grains; the remainder, the unliberated grains occur in composite particles with one or more other minerals. These are classified into a four-fold classification based on their volume % of the host particle, and hence its probable behaviour during flotation (See PETROGRAPHIC AND IMAGE ANALYSIS). The raw liberation data are tabulated in appendix B, and the raw association data are tabulated in appendix C.

MATERIAL BALANCES OF MINERAL LIBERATIONS AND ASSOCIATIONS

The raw liberation, classification and association data for chalcopyrite and sphalerite, and the liberation data for galena and pyrite in each of the end product samples were transformed into coherent sets of data by material balance calculations. The liberation and classification data for chalcopyrite and sphalerite were first weighted in terms of the amount of the mineral(s) present in each product using the corresponding assays for Cu and Zn as the more precise modal equivalents of these minerals e.g. the Cu assay was multiplied by the liberation (% free) of chalcopyrite in that product. These raw modal fractions of the Cu assay were transformed by MATBAL into sets of adjusted modal fractions of the Cu assay and recoveries for the same were calculated. The adjusted modal fractions were subsequently divided by the respective Cu assay for that product, to give adjusted, but non-coherent liberations. Thus, a set of adjusted liberations is not generated, but is extracted from two sets of coherent data. This procedure was done on (1) the four-fold classification and the associations for chalcopyrite and sphalerite (using the Cu and Zn assays, respectively), and (2) the liberation data (i.e. % free and % unliberated) for galena and pyrite (using the galena and pyrite mineral quantities).

CHALCOPYRITE

The raw modal fraction of the adjusted Cu assay occurring as free, unliberated, sub-free, middling and sub-middling chalcopyrite grains in each end product are given in Table 8. The adjusted equivalents of each of these categories are given in Table 9, whereas the corresponding recoveries of these are given in Table 10. The Cu recovery in each product was multiplied by the adjusted modal fraction of each category of chalcopyrite to give the adjusted modal fraction of the Cu recovery occurring as free, sub-free, middling and sub-middling chalcopyrite in each product. The latter data are given in Table 11, and plotted as histograms on a simplified circuit diagram in Figure 1. The first row of data in Table 11 gives the adjusted classification of chalcopyrite in the feed, which is: 53.2 % occur as free, 34.6 % as sub-free, 6.33 % as middling and 5.91 % as sub-middling grains of chalcopyrite.

Of the chalcopyrite in the feed 53.2 % occurs as free and 34.6 % as sub-free grains. Thus, 87.8 % of the chalcopyrite occurs as free plus sub-free or 'recoverable' grains, constituting relatively high 'effective' liberation. These grains are expected to behave as free grains and hence be recovered in the Cu-concentrate. Of these, 99.3 % of the free and 95.3 % of the sub-free grains are recovered in the Cu-concentrate (See Table 10), and account for 85.5 of the 91.4 % (i.e. 93.6 %) Cu-recovery in the Cu-concentrate (See Table 11). The remainder of the 'recoverable' chalcopyrite, much of which is 'over-sized', is recovered in the Zn-concentrate (i.e. 0.04 % of the free and 1.54 % of the sub-free), and tailings (i.e. 0.70 % of the free and 3.20 % of the sub-free). The relatively minimal losses of approximately 2.5 % of these 'recoverable' grains correspond to 2.1 % of the chalcopyrite in the feed. These losses account for approximately 65 % of the chalcopyrite in the Zn-concentrate (See Plate 1D), and 20 % of the chalcopyrite in the tailings (See Plate 1E). Losses of 'recoverable' grains of this magnitude are within

TABLE 8

RAW CHALCOPYRITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Total Cu Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Cu assay)				
Feed	2.39	1.51	0.88	0.50	0.26	0.12
Cu-Conc.	22.5	9.67	12.8	11.5	1.02	0.25
Zn-Conc.	0.81	0.02	0.79	0.50	0.09	0.20
Tails.	0.21	0.01	0.20	0.03	0.03	0.14

the limits of routine and acceptable losses.

In addition to the 87.8 % recoverable chalcopyrite in the feed, 6.33 % occurs as middling grains and 5.91 % as sub-middling grains. The middling grains are largely recovered in the Cu-concentrate (i.e. 77.5 %), with 1.54 % recovered in the Zn-concentrate, but with 21.0 % rejected to the tailings. These losses correspond to 0.10 and 1.54 %, respectively of the chalcopyrite in the feed. As middling grains are the most amenable to regrinding, the combined loss (to the Zn-concentrate and tailings) of these grains, accounting for only 1.64 % of the chalcopyrite in feed (See Table 11), mitigates any significant improvement in liberation from this category by regrinding. Thus, regrinding should be largely directed at the sub-middling fraction of chalcopyrite.

The sub-middling grains comprise only 5.91 % of the chalcopyrite in the feed and are largely rejected to the tailings (i.e. 78.5 %), with

TABLE 9

ADJUSTED CHALCOPYRITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Total Cu Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Cu assay)				
Feed	2.39	1.26	1.01	0.82	0.15	0.14
Cu-Conc.	22.5	12.9	8.40	8.03	1.19	0.25
Zn-Conc.	0.81	0.02	0.79	0.50	0.09	0.20
Tails.	0.21	0.01	0.19	0.03	0.04	0.12

TABLE 10

RECOVERY OF CHALCOPYRITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Cu Recovery	Free	Unliberated	Sub-free	Middling	Sub-middling
		Recovery (%)				
Feed	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	91.4	99.3	81.1	95.3	77.5	17.7
Zn-Conc.	0.86	0.04	1.99	1.54	1.47	3.81
Tails.	7.70	0.70	16.9	3.20	21.0	78.5

recoveries of only 17.7 % in the Cu-concentrate. The sub-middling grains rejected to the tailings correspond to 4.62 % of the chalcopyrite in the feed, and account for approximately 60 % of the chalcopyrite in the tailings. The loss of 3.81 % of the sub-middling grains to the Zn-concentrate corresponding to 0.21 % of the chalcopyrite in the feed, is due in part to chalcopyrite-disease in sphalerite, but principally due to granular and diablastic chalcopyrite in sphalerite (See Plate 1F). The combined loss of 82 % of the sub-middling chalcopyrite grains to the Zn-concentrate and particularly the tailings, corresponding to 4.8 % of the chalcopyrite in the feed, is the largest fraction of unrecovered chalcopyrite. These losses are only redressable by extremely fine regrinding of streams preferentially enriched in the sub-middling fraction.

Extremely fine regrinding (i.e. 80 % - 26 um) of a stream preferentially enriched in the middling and particularly sub-middling fractions of chalcopyrite is recommended to increase the liberation and

TABLE 11

RECOVERY OF THE Cu ASSAY IN THE FOUR STALL LAKE END PRODUCTS IN TERMS OF THE MODAL FRACTION OF CHALCOPYRITE OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS.

PRODUCT	Cu Recovery	Free	Sub-free	Middling	Sub-middling
		Recovery (%)			
Feed	100.0	53.2	34.6	6.33	5.91
Cu-Conc.	91.4	52.7	32.8	4.86	1.02
Zn-Conc.	0.86	0.02	0.53	0.10	0.21
Tails.	7.70	0.39	1.16	1.54	4.62

recovery of chalcopyrite. Regrinding would also address the losses of 'over-sized' sub-free chalcopyrite (See Table 13 of appendix B), which comprise a significant proportion of the sub-free chalcopyrite in the feed that is rejected to the Zn-concentrate (i.e. 0.53 %;See Plate 1D) and tailings (i.e. 1.16 %;See Plate 1E). Because sub-free grains comprise 34.6 % of the chalcopyrite in the feed, the combined loss (to the Zn-concentrate and tailings) of only 4.74 % of these is of equivalent magnitude to the higher losses of 22.5 % of the smaller middling fraction (i.e. 6.33 % of the chalcopyrite in the feed). Nonetheless, the losses of Cu as sub-free and middling grains of chalcopyrite account for only 1.69 % and 1.64 %, respectively of the Cu in the feed, whereas those as sub-middling grains of chalcopyrite account for 4.83 % of the Cu in the feed. Thus, improved liberation through regrinding of the sub-middling category of chalcopyrite is the most likely course of action that might attain minor, yet increased Cu recovery. A regrind would also tend to increase the Cu-concentrate grade.

The raw mineral association data for chalcopyrite (Table 1 of appendix C) were material balance adjusted (Table 2 of appendix C) and recoveries of these were calculated (See Table 12). Also given on the first row of data in Table 12 are the modal percentages of chalcopyrite occurring in each specific association category of chalcopyrite. It is apparent from these data that the bulk of the chalcopyrite is free (as discussed above), and that the largest fraction of the unliberated grains occur as ternary particles (i.e. 26.7 %), with lesser fractions as binary particles of chalcopyrite-sphalerite (i.e. 11.2 %), chalcopyrite-gangue (i.e. 3.74 %), chalcopyrite-pyrite (i.e. 1.40 %) and chalcopyrite-galena (i.e. 0.47 %).

All these categories show only minor losses to the Zn-concentrate (i.e. <3.17 %), but with losses of variable magnitude to the tailings (from 0.72 % of the free, to 66 % of the chalcopyrite-galena category). The losses of 0.72 % of the free grains are minimal and are not discussed

TABLE 12

RECOVERY OF THE MINERAL ASSOCIATIONS OF CHALCOPYRITE IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Cu Recovery	Free Cpy	Cpy+Py	Cpy+Gan	Cpy+Sph	Cpy+Gal	Ternary Cpy
Feed	-----	56.5	1.40	3.74	11.2	0.47	26.7
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	91.4	99.2	68.7	86.1	87.1	31.8	73.6
Zn-Conc.	0.86	0.04	0.99	3.17	1.51	2.20	2.42
Tailings	7.70	0.72	30.3	10.8	11.4	66.0	24.0
Tailings	-----	4.45	3.92	4.36	13.7	3.87	69.7

Note: The first and last rows of data present the adjusted modal percents of chalcopyrite occurring in specific association categories in the feed and tailings, respectively. These were calculated by dividing the Cu assay by the corresponding adjusted modal fraction of the Cu assay occurring in each category (See Table 2 of appendix C).

further (See above). Although 66.0 % of the chalcopyrite-galena particles are rejected to the tailings, the magnitude of these losses is relatively insignificant (i.e. 3.87 %) as these particles comprise only 0.47 % of the chalcopyrite in the feed. The relatively high losses of 30.3 % of the chalcopyrite-pyrite particles to the tailings only account for 0.4 % of the chalcopyrite in the feed, and 3.92 % of the chalcopyrite in the tailings. Similarly, because chalcopyrite-gangue particles comprise only 3.74 % of the chalcopyrite in the feed, the loss of 10.8 % of these to the tailings accounts for only 4.36 % of the chalcopyrite in the tailings.

The largest two fractions of chalcopyrite rejected to the tailings are ternary chalcopyrite and chalcopyrite-sphalerite particles (i.e. 69.7 and 13.7 %, respectively of the chalcopyrite in the tailings). Petrographic examination shows that the chalcopyrite-sphalerite particles rejected to the tailings consist principally of sub-middling chalcopyrite locked (as granular, diablastic and as chalcopyrite-disease) in sub-free grains of sphalerite. The petrographic examination also shows that the ternary chalcopyrite particles rejected to the tailings consist principally of fine-grained, subordinate chalcopyrite grains (i.e. sub-middling), much of which is not readily amenable to liberation by regrinding. However, many of the ternary chalcopyrite particles consist of chalcopyrite locked with pyrite and/or pyrrhotite in medium- to coarse-grained, sub-free sphalerite that are amenable to regrinding.

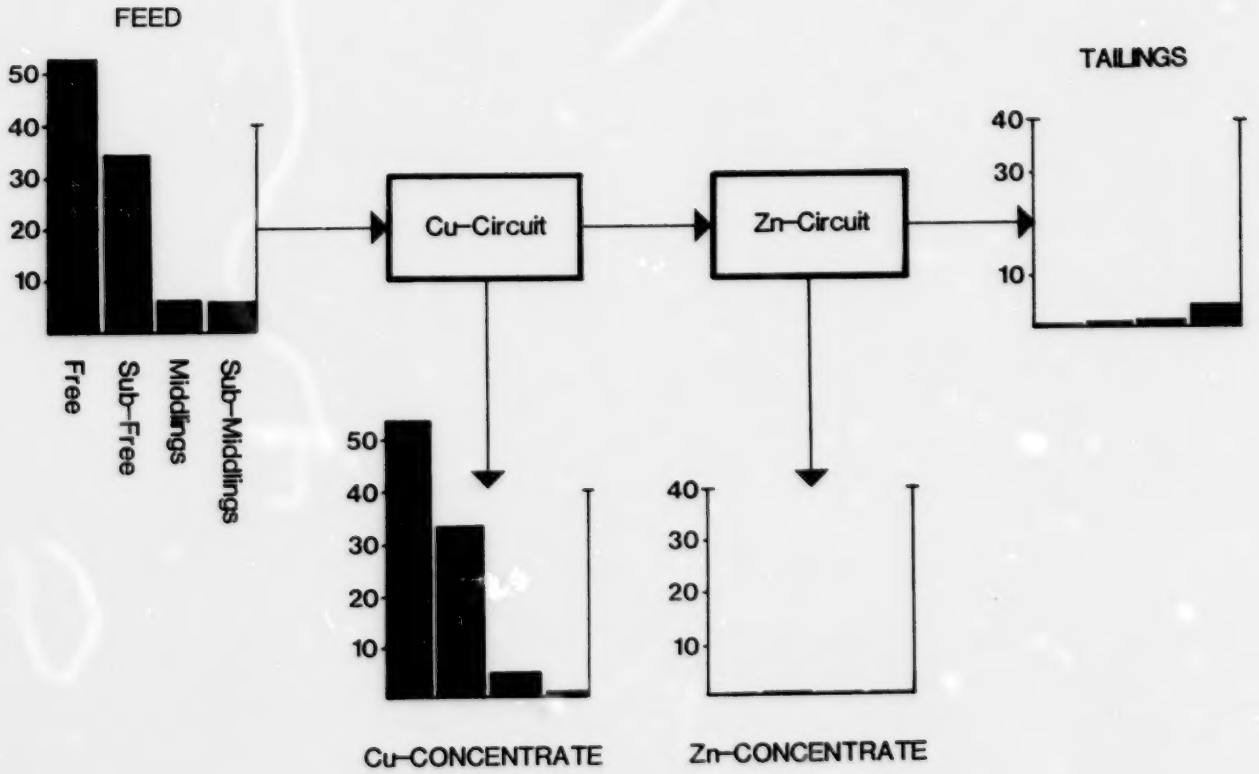


FIGURE 1.
THE MODAL FRACTION OF THE Cu RECOVERY MODELLED IN TERMS OF THAT OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS OF CHALCOPYRITE IN THE FOUR STALL LAKE END PRODUCTS.

SPHALERITE

The raw modal fraction of the adjusted Zn assay occurring as free, unliberated, sub-free, middling and sub-middling sphalerite grains in each end product are given in Table 13. The adjusted equivalents of each of these categories are given in Table 14, whereas the corresponding recoveries of these are given in Table 15. The Zn recovery in each product was multiplied by the adjusted modal fraction of each category of sphalerite to give the adjusted modal fraction of the Zn recovery occurring as free, sub-free, middling and sub-middling sphalerite in each product. The latter data are given in Table 16, and plotted as histograms on a simplified circuit diagram in Figure 2. The first row of data in Table 16 gives the adjusted classification of sphalerite in the feed, which is: 62.5 % occur as free, 24.6 % as sub-free, 6.25 % as middling and 6.70 % as sub-middling grains.

Although 62.5 % of the sphalerite in the feed occurs as free grains (i.e. % liberation), a further 24.6 % occurs as sub-free grains. Thus, 87.1 % of the sphalerite occurs as free plus sub-free grains. This relatively high fraction of 'recoverable' grains of sphalerite indicates relatively high 'effective' liberation. While 73.5 % and 12.0 % of the free grains are recovered in the Zn- and Cu-concentrates, respectively, only 32.5 % and 20.2 % of the sub-free grains are recovered in these same concentrates, respectively. Consequently, 14.5 % of the free, and 41.1 % of the sub-free grains of sphalerite are rejected to the tailings (See Plate 1G). Thus, only approximately 59 % of the 'recoverable' sphalerite is recovered in the Zn-circuit, although approximately 66 % of the 'recoverable' sphalerite entering the Zn-circuit is recovered in the Zn-concentrate. These extremely high losses of 'recoverable' sphalerite indicate poor sphalerite rejection from the Cu-circuit (See Plate 1H), and poor sphalerite flotation in the Zn-circuit (See values in parentheses in Table 15). Because the 'recoverable' grains of sphalerite constitute 87.1 % of the sphalerite in the feed, the losses of approximately 12 % and 30 % of these grains to the Cu-concentrate and tailings, respectively has a profoundly negative impact on the Zn-metallurgy. These losses to the Cu-concentrate and tailings correspond to 9.36 and 25.8 %, respectively of the sphalerite in the feed, and account for approximately 60 % and 75 % of the sphalerite in the Cu-concentrate and tailings, respectively. Thus, approximately 60 % and 75 % of the sphalerite lost to the Cu-concentrate and tailings, respectively is essentially liberation-independent; are expected (from a liberation standpoint only) to be recovered in the Zn-concentrate.

In addition to the 87.1 % recoverable sphalerite in the feed, 6.25 % occurs as middling grains. Only 9.13 % of these grains are recovered in the Zn-concentrate, corresponding to 0.50 % of the sphalerite in the feed. The Cu-concentrate recovers 66.5 % of the middling sphalerite, corresponding to 3.63 % of the sphalerite in the feed, and accounting for approximately 24 % of the sphalerite in the Cu-concentrate. These grains probably largely correspond to sphalerite grains locked with chalcopyrite. Furthermore, 24.4 % of the middling sphalerite is rejected to the tailings, corresponding to 2.1 % of the sphalerite in the feed, but only accounts for approximately 6.2 % of the sphalerite in the tailings.

TABLE 13

RAW SPHALERITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Total Zn Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Zn assay)				
Feed	2.50	1.77	0.73	0.42	0.20	0.12
Cu-Conc.	3.90	1.68	2.22	0.73	0.82	0.68
Zn-Conc.	51.0	36.2	14.8	14.2	0.48	0.09
Tailings	0.94	0.23	0.72	0.34	0.04	0.34

TABLE 14

ADJUSTED SPHALERITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Total Zn Assay	Free	Unliberated	Sub-free	Middling	Sub-middling
		(Modal Fraction of the Zn assay)				
Feed	2.50	1.40	0.97	0.55	0.14	0.15
Cu-Conc.	3.90	1.71	2.01	0.69	0.93	0.57
Zn-Conc.	51.0	40.2	12.4	10.2	0.49	0.09
Tailings	0.94	0.24	0.52	0.26	0.04	0.10

Middling grains are the principal category of particle amenable to increased liberation and recovery through regrinding. Although only 6.25 % of the sphalerite in the feed occurs as middling grains, 91 % of these are lost to the Cu-concentrate and tailings combined, such that enhanced liberation and recovery from these grains by regrinding is nominally expected to be relatively significant (i.e. ≤5 %).

Of the 6.70 % of the sphalerite in the feed that occurs as sub-middling grains, only approximately 0.1 % (i.e. 1.58 %) is recovered in the Zn-concentrate, 2.2 % (i.e. 37.9 %) is recovered in the Cu-concentrate, and 5.2 % (i.e. 60.5 %) is recovered in the tailings. It is stressed that the sum of the fractions of sub-middling grains of sphalerite in the Cu-concentrate (0.09 %), Zn-concentrate (2.22 %) and tailings (5.16 %) is 7.47 %, and is in excess of the 6.70 % sub-middling sphalerite in the feed (See Table 16). Although this excess of sub-middling grains above that in the feed (which is due to cross-balancing errors) is large, the data is considered relatively coherent, and adequate to elucidate the behaviour,

TABLE 15

RECOVERY OF SPHALERITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Zn Recovery	Free	Unliberated	Sub-free	Middling	Sub-middling
		Recovery (%)				
Feed	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	15.2	12.0	20.2	12.1	66.5	37.9
Zn-Conc.	51.9	73.5	32.5	46.9	9.13	1.58
	(61.2)	(83.5)	(40.7)	(53.4)	(27.3)	(2.54)
Tailings	33.0	14.5	47.2	41.1	24.4	60.5

Note: Values in parenthesis show the recovery in the Zn-concentrate of each parameter as a function of that in the Zn-circuit feed.

and identify the principal losses of sub-middling sphalerite grains. The losses of sub-middling sphalerite to the Cu-concentrate constitute approximately 15 % of the sphalerite in the Cu-concentrate, whereas those rejected to the tailings constitute approximately 16 % of the sphalerite in the tailings. These combined losses of approximately 6.5 % of the sphalerite in the feed, corresponding to 98 % of the sub-middling sphalerite, are essentially unrecoverable without recourse to extremely

TABLE 16

RECOVERY OF THE Zn ASSAY IN THE FOUR STALL LAKE END PRODUCTS IN TERMS OF THE MODAL FRACTION OF SPHALERITE OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS.

PRODUCT	Zn Recovery	Free	Sub-free	Middling	Sub-middling
		Recovery (%)			
Feed	100.0	62.5	24.6	6.25	6.70
Cu-Conc.	15.2	6.67	2.69	3.63	2.22
Zn-Conc.	51.9	40.9	10.4	0.50	0.09
Tailings	33.0	12.4	13.4	2.06	5.16

fine regrinding.

Although 13.7 % of the sphalerite (or 15.2 % of the Zn) in the feed is recovered in the Cu-concentrate, the classification of this in terms of the liberation categories of the constituent sphalerite is 6.67 % free, 2.69 % sub-free, 3.63 % middling and 2.22 % sub-middling grains. Thus, 44 %, 18 %, 24 % and 14 % of the sphalerite in the Cu-concentrate occur as free, sub-free, middling and sub-middling grains of sphalerite, respectively. The combined recovery in the Cu-concentrate of 'recoverable' grains of sphalerite is approximately 12 %, which corresponds to 9.4 % of the sphalerite in the feed, and approximately 62 % of the sphalerite in the Cu-concentrate. Thus, 62 % of the sphalerite lost to the Cu-concentrate is recoverable (to the Zn-concentrate), confirmimg that the sphalerite losses are only in part due to poor liberation, but are largely due to poor rejection of sphalerite in the Cu-circuit.

The raw mineral association data for sphalerite (Table 3 of appendix C) were material balance adjusted (Table 4 of appendix C) and recoveries of these were calculated (See Table 17). Also given on the first and last rows of data in Table 17 are the modal percentages of sphalerite occurring in each specific association category of sphalerite in the corresponding product. It is apparent from these data that the bulk of the sphalerite is free (as discussed above), and that the largest fraction of the unliberated grains occur as ternary particles (i.e. 17.3 %), with lesser fractions as binary particles of sphalerite-chalcopyrite (i.e. 13.6%), sphalerite-gangue (i.e. 8.48 %), sphalerite-pyrite (i.e. 1.27 %) and sphalerite-galena (i.e. 0.85 %).

The above categories show losses to the Cu-concentrate that are less than those of total sphalerite to the Cu-concentrate (i.e. <13.7 %), except for the sphalerite-chalcopyrite (i.e. 25.9 %) and ternary sphalerite (i.e. 23.9 %) categories. The latter two categories are preferentially recovered in the Cu-concentrate due to the influence exerted on the particles' flotation behaviour by the constituent locked chalcopyrite. Petrographic examination of the Cu-concentrate shows that the ternary particles consist predominantly of chalcopyrite-sphalerite-pyrite and chalcopyrite-sphalerite-pyrrhotite, whereas the binary sphalerite-chalcopyrite particles consist of predominantly granular sub-free, middling and sub-middling particles. The exceptionally high recovery of middling sphalerite to the Cu-concentrate (i.e. 66.5 %) is due overwhelmingly to sphalerite occurring in binary or ternary particles containing middling chalcopyrite.

All the categories show significant losses to the tailings (i.e. 15 % of the free, to 69 % of the sphalerite-pyrite category). The losses of 15 % of the free grains are not discussed further here (See above). Although 38.8 % of the sphalerite-galena particles are rejected to the tailings, the magnitude of these losses is relatively insignificant (i.e. 1.46 %), as these particles comprise only 0.85 % of the sphalerite in the feed. The extremely high losses of 69 % of the sphalerite-pyrite particles to the tailings is also relatively insignificant as these grains only account for 1.27 % of the sphalerite in the feed, and 2.93 % of the sphalerite in the tailings. Because sphalerite-gangue particles comprise 8.48 % of the sphalerite in the feed, the loss of 37.3 % to the tailings accounts for 13.2 % of the sphalerite in the tailings. Similarly,

TABLE 17

RECOVERY OF THE MINERAL ASSOCIATIONS OF SPHALERITE IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Zn Recovery	Free Sph	Sph+Py	Sph+Gan	Sph+Cpy	Sph+Gal	Ternary Sph
Feed	2.50	58.6	1.27	8.48	13.6	0.85	17.3
Feed	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cu-Conc.	15.2	12.0	3.46	9.54	25.9	4.17	23.9
Zn-Conc.	51.9	73.4	27.4	53.2	46.6	57.0	26.1
Tailings	33.0	14.6	69.2	37.3	27.5	38.8	50.0
Tailings	----	33.7	2.93	13.2	14.6	1.46	34.1

Note: The first and last rows of data present the adjusted modal percents of sphalerite occurring in specific association categories in the feed and tailings, respectively. These were calculated by dividing the Zn assay by the corresponding adjusted modal fraction of the Zn assay occurring in each category (See Table 4 of appendix C).

sphalerite-chalcopyrite particles comprise 13.6 % of the sphalerite in the feed, the loss of 27.5 % to the tailings accounts for 14.6 % of the sphalerite in the tailings. Thus, a minor yet significant (i.e. 14.6 %) fraction of the sphalerite rejected to the tailings occurs in particles that, from a liberation standpoint, are recoverable to the Zn-concentrate (i.e. both chalcopyrite and sphalerite are expected to float in the Zn-circuit). Petrographic examination of the tailings shows that the bulk of the binary sphalerite-chalcopyrite particles consist of medium-grained to minor 'over-sized', sub-free sphalerite with sub-middling chalcopyrite. Regrinding a stream enriched in these particles forward of the Zn-circuit, may result in only minor improved Cu and Zn recoveries.

The principal losses of sphalerite to the tailings occur in two of the association categories: (1) free sphalerite grains, and (2) ternary sphalerite particles. As shown by the liberation analysis of sphalerite (See Table 16), approximately one third of the sphalerite in the tailings is free. However, the association analysis also shows that another third occurs as ternary particles (See Table 17), and these correspond to sub-free, middling and sub-middling sphalerite grains. In as much as two thirds of the unliberated sphalerite in the tailings is sub-free, the bulk of the ternary sphalerite particles are thus also sub-free. Petrographic examination confirmed that these ternary particles consist largely of sub-

free sphalerite containing sub-middling chalcopyrite, pyrrhotite and/or pyrite. From a liberation standpoint, these particles are expected to behave as free sphalerite grains, and be recovered in the Zn-concentrate.

The host particle size distributions of both free and sub-free sphalerite in the tailings are 80 % -35 um and 80 % -74 um, respectively (See Figure 3), and show that the sphalerite is largely medium-grained with only minor 'over-sized', and negligible slime components. Interestingly, whereas the size distributions of free sphalerite in the Zn-concentrate and tailings are essentially identical (i.e. approx. 80 % -35 um), that of sub-free sphalerite in the tailings is coarser-grained than that in the Zn-concentrate (i.e. 80 % -74 um Vs 80 % -50 um). The losses of free and sub-free sphalerite, which comprise approximately 75 % of the sphalerite in the tailings, and which are liberation-independent, occur for particles whose size range exceeds that of particles which float into the Zn-concentrate. Nonetheless, the losses to the tailings are largely attributed to poor flotation and circuit efficiency in the recovery of grains which fall within routinely 'recoverable' particle liberation (i.e. >70 % of particle) and size (i.e. <100 um) limits.

The host particle size distributions of free and sub-free sphalerite in the Cu-concentrate are also shown in Figure 3. Free and sub-free sphalerite account for approximately 62, 99, 75 % of the sphalerite in the Cu-concentrate, Zn-concentrate and tailings, respectively, and thus comprise the bulk of the sphalerite in each of these products. It should be noted that the grain size and host particle size distributions for free and sub-free grains of a mineral of interest are comparable. Thus, the trends in the data plotted in Figure 3 are largely indicative of the influence exerted by grain size on the principal fractions of recovered and unrecovered sphalerite. A systematic trend of coarsening particle size of free and sub-free sphalerite in the Cu-concentrate to the Zn-concentrate to the tailings is apparent from Figure 3. Only in the case of the Cu-concentrate is the fraction of slime sphalerite potentially significant, with 17 % of the free and 7 % of the sub-free grains occurring in particles less than 5 um in diameter. However, greater than 85 % of the free and sub-free sphalerite in each of these products occurs within the optimum flotation particle size range of 5 to 100 um. Nonetheless, there is a strong tendency for finer-grained 'recoverable' sphalerite to be recovered in the Cu-concentrate, as observed in the Trout Lake Cu-concentrate by Healy & Petruk (1989a), and in the HBMS Cu-concentrate by Healy & Petruk (1989b), and for coarser-grained 'recoverable' sphalerite to be rejected to the tailings.

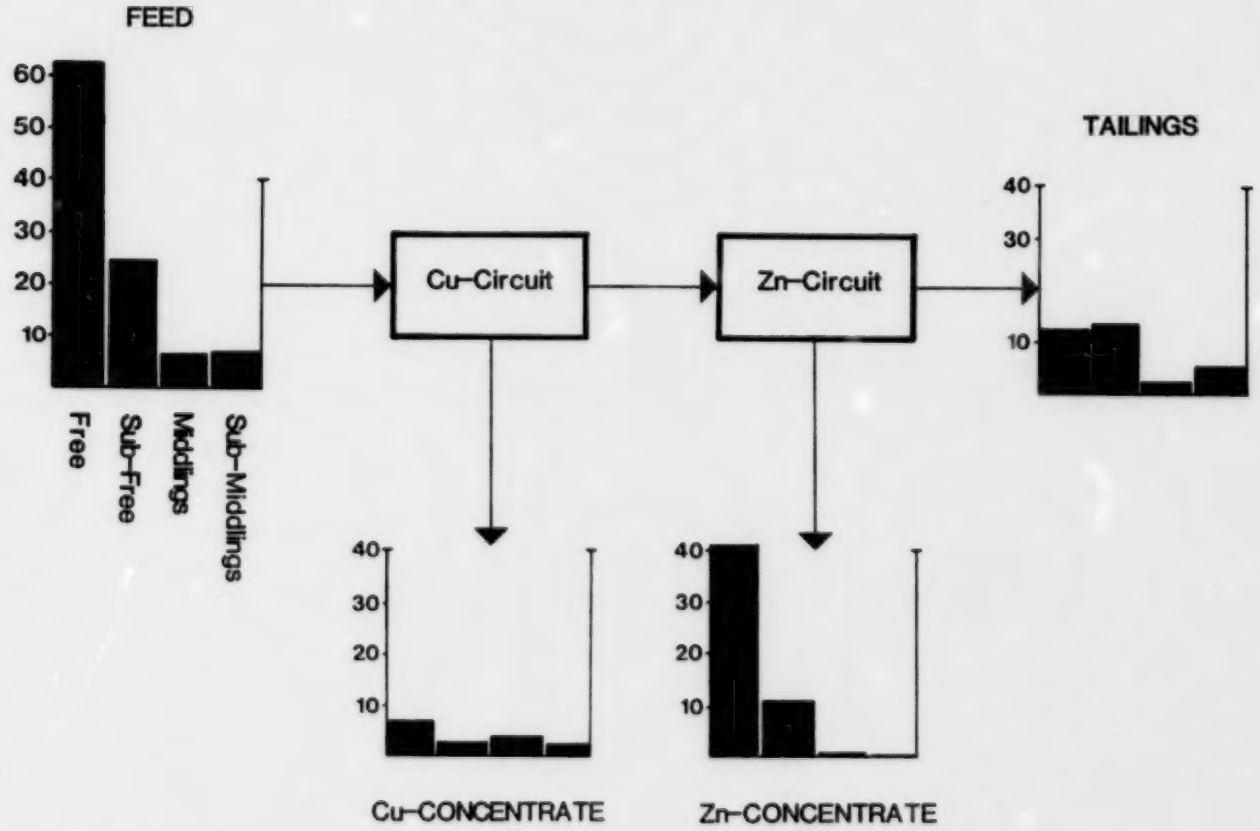


FIGURE 2.
THE MODAL FRACTION OF THE ZN RECOVERY MODELLED IN TERMS OF THAT OCCURRING AS FREE, SUB-FREE, MIDDLING AND SUB-MIDDLING GRAINS OF SPHALERITE IN THE FOUR STALL LAKE END PRODUCTS.

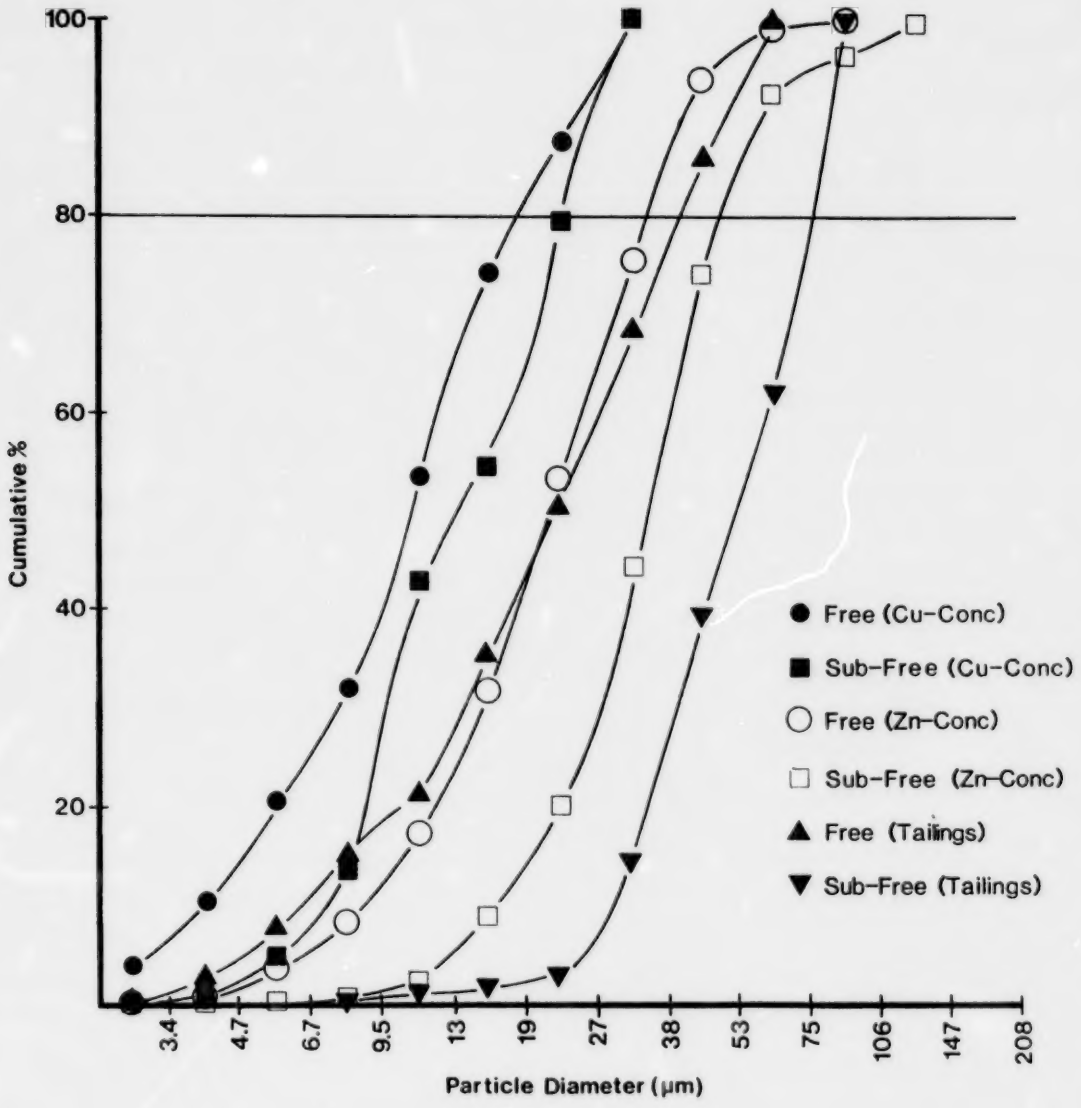


FIGURE 3.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF FREE AND SUB-FREE SPHALERITE IN THE STALL LAKE Cu-CONCENTRATE, Zn-CONCENTRATE AND TAILINGS.

GALENA AND PYRITE

The raw modal fractions of the galena and pyrite modal quantities occurring as free and unliberated grains in each end product are given in Table 18. The adjusted equivalents of each of these categories are given in Table 19, whereas the corresponding recoveries of these are given in Table 20. The % free and % unliberated were calculated from the adjusted modal fractions of galena and pyrite occurring as free and unliberated grains in the feed (See Table 19) and these are given on the first row of data in Table 20. It is apparent from these data that the liberation of galena and pyrite in the feed is 20.7 and 70.4 %, respectively. Thus, even if galena did not behave inertly during flotation, relatively high losses of galena may be expected, contingent on the character of the predominant accompanying locked mineral(s). Furthermore, relatively high rates of

TABLE 18

RAW GALENA AND PYRITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	GALENA		PYRITE	
	Free	Unliberated	Free	Unliberated
	Modal Fractions			
Feed	0.05	0.25	23.9	8.40
Cu-Conc.	0.04	0.28	3.91	3.51
Zn-Conc.	0.21	0.36	0.39	1.07
Tails.	0.07	0.22	23.8	12.2

pyrite rejection to the tailings may also be expected.

The low overall liberation reflects the fine-grain size of galena and its occurrence largely as sub-middling grains in coarse particles (See Figure 1 of appendix D). The rejection of approximately 85 % of both the free and unliberated galena to the tailings with only minor recoveries to the Cu- and Zn-concentrates is consistent with the essentially inert flotation characteristics exhibited by galena (Healy & Petruk 1989a, 1989b). The slightly higher recoveries of unliberated galena to the Cu-concentrate is consistent with the relative abundance of chalcopyrite-galena particles, as observed petrographically.

The 70.4 % liberation of pyrite in the feed is high, and in part reflects (1) the recrystallized nature of the pyrite with negligible inclusions of other minerals, and (2) the probably coarse-grain size of pyrite in the unbroken ore, due to the high temperature and extensive recrystallization during metamorphism. The host particle size distribution

TABLE 19

ADJUSTED GALENA AND PYRITE SPHALERITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	GALENA		PYRITE	
	Free	Unliberated	Free	Unliberated
	Modal Fractions			
Feed	0.06	0.23	22.4	9.42
Cu-Conc.	0.04	0.28	3.91	3.49
Zn-Conc.	0.21	0.36	0.39	1.07
Tails.	0.06	0.22	25.1	10.3

TABLE 20

RECOVERY OF GALENA AND PYRITE LIBERATIONS IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	GALENA		PYRITE	
	Free	Unliberated	Free	Unliberated
Feed	20.7	79.3	70.4	29.6
Feed	100.0	100.0	100.0	100.0
Cu-Conc.	6.12	11.8	1.70	3.61
Zn-Conc.	9.12	3.93	0.04	0.29
Tailings	84.8	84.2	98.3	96.1

Note: The first row of data presents the adjusted modal percents of galena and pyrite occurring as free and unliberated grains in the feed. These were calculated from the data in Table 19.

of pyrite in the feed (i.e. 80 % - 22 um) is finer than those of chalcopyrite, sphalerite and galena (See Figue 1 of appendix D), and simply reflects the highly liberated state of pyrite (i.e. grain and host particle sizes are almost identical). Of the free and unliberated pyrite in the feed, 98.3 and 96.1 %, respectively are rejected to the tailings, resulting in the 97.7 % rejection of total pyrite to the tailings (See Table 7). The bulk of the recovered pyrite reports to the Cu- rather than

the Zn-concentrate, reflecting the lower grade Cu-concentrate and less selective Cu-flotation. However, whereas 1.70 % of the free and 3.61 % of the unliberated pyrite are recovered in the Cu-concentrate, 12 % of the free and 20.2 % of the unliberated sphalerite are recovered in the Cu-concentrate. Sphalerite is thus recovered at approximately six times the rate of pyrite into the Cu-concentrate, irrespective of its state of liberation. This indicates that the loss of sphalerite to the Cu-concentrate is not simply the product of mechanical entrainment, but most probably reflects poor selective flotation, and perhaps activation of sphalerite in the Cu-circuit.

CONCLUSIONS

1. Material balance calculated composition of the feed in terms of the valuable metals, showed that the feed contained:

   2.39 % Cu 2.50 % Zn 1.60 ppm Au 14.1 ppm Ag 0.09 % Pb

   The feed contained relatively low levels of Cu, and high levels of Zn, Au and Ag relative to 'normal' feeds.

2. Material balance modelling of the raw chemical assays for the valuable metals Cu, Zn, Au, Ag and Pb through the circuit under simulated steady state conditions gives the following recoveries (%) :

	Cu-Conc.	Zn-Conc.	Tailings.
Cu	91.4	0.86	7.70
Zn	15.2	51.9	33.0
Au	56.4	1.63	42.0
Ag	77.3	3.29	19.4
Pb	19.8	20.2	60.0

3. The distribution of the recoveries of each of the 7 elements indicates four principal groups of elements exhibiting relatively uniform distribution in the products. These are:

   a) Group 1: Recovered principally in the Cu-concentrate i.e. Cu, Ag and Au.

   b) Group 2: Recovered principally in the Zn-concentrate i.e. Zn.

   c) Group 3: Rejected principally to the tailings i.e. Fe, Pb and S.

4. The mineralogical composition (in vol %) of the feed was calculated by material balance adjusting the image analysis data. This is given below:

   45.7 % Gangue (i.e. silicates and carbonates)
   32.3 % Pyrite (including minor magnetite and marcasite)
   7.94 % Pyrrhotite
   6.86 % Chalcopyrite
   4.37 % Sphalerite
   0.296 % Galena
   0.109 % Arsenopyrite

   The quantities of the trace minerals tetrahedrite, stannite, boulangerite, cassiterite, gudmundite and altaite were not determined.

5. The distribution of the recoveries of each of the 7 minerals whose modal quantities were determined, and which were material balance

modelled through the circuit, indicate four principal groups of minerals, each with relatively uniform flotation behaviour. These are:

a) Group 1: Inert minerals which are principally rejected to the tailings i.e. gangue and pyrite.

b) Group 2: Minerals with high rejection (i.e. >85 %) to the tailings and low recoveries (i.e. <10 %) in the Cu- and Zn-concentrates i.e. pyrrhotite, galena and arsenopyrite.

c) Group 3: Minerals principally recovered in the Cu-concentrate i.e. chalcopyrite.

d) Group 4: Minerals principally recovered in the Zn-concentrate i.e. sphalerite.

6. The simplified classification of chalcopyrite in the feed, in terms of the liberation categories is 53.2 % free, 34.6 % sub-free, 6.33 % middling and 5.91 % sub-middling grains. This is shown in the table below, along with the recoveries of each category.

CHALCOPYRITE	FREE	SUB-FREE	MIDDLING	SUB-MIDDLING	TOTAL	Cu-Rec.
LIBERATION in the float feed	53.2	34.6	6.33	5.91	___	100.0
RECOVERY in the Cu-Conc.	99.3	95.3	77.5	17.7	93.1	91.4
RECOVERY in the Zn-Conc.	0.04	1.54	1.47	3.81	0.69	0.86
RECOVERY in the Tailings	0.70	3.20	21.0	78.5	6.26	7.70

a) While 53.2 % of the chalcopyrite in the feed occurs as free grains 87.8 % occurs as free plus sub-free grains. This relatively high fraction of 'recoverable' grains of chalcopyrite indicates high 'effective' liberation. The Cu-concentrate recovers 99.3 % of the free grains and 95.3 % of the sub-free grains, which is largely responsible for the recovery of 93.1 % of the chalcopyrite to the Cu-concentrate. The remainder of the recoverable grains of chalcopyrite is recovered in the tailings (i.e. 0.70 % of the free and 3.20 % of the sub-free) and Zn-concentrate (i.e. 0.04 % of the free and 1.54 % of the sub-free). The relatively minimal losses of approximately 2.5 % of

these 'recoverable' grains account for approximately 65 % of the chalcopyrite in the Zn-concentrate, and 20 % of the chalcopyrite in the tailings. These are within the limits of routine and acceptable losses.

b) A further 6.33 % of the chalcopyrite in the feed occurs as middling grains, which are largely recovered in the Cu-concentrate (i.e. 77.5 %). The bulk of the unrecovered middling grains (i.e. 21 %) are rejected to the tailings, and account for 1.5 % of the chalcopyrite in the feed. Regrinding a stream enriched in these grains may yield minor (i.e. ≤1 %) improvement in Cu recovery.

c) Sub-middling grains comprise 5.91 % of the chalcopyrite in the feed and are largely rejected to the tailings (i.e. 78.5 %), with only 17.7 % recovered in the Cu-concentrate. The grains rejected to the tailings correspond to 4.6 % of the chalcopyrite in the feed, and account for approximately 60 % of the chalcopyrite in the tailings. The combined loss of 82 % of the sub-middling grains (principally to the tailings), corresponding to 4.8 % of the chalcopyrite in the feed, is the largest fraction of rejected chalcopyrite. These losses are only redressable by extremely fine regrinding of streams preferentially enriched in the sub-middling fraction.

7. The classification of sphalerite in the feed, in terms of the liberation categories is 62.5 % free, 24.6 % sub-free, 6.25 % middling and 6.70 % sub-middling grains. This is shown in the table below, along with the recoveries of each category. Values in parenthesis show the recovery in the Zn-concentrate of each parameter as a function of that in the Zn-circuit feed.

SPHALERITE	FREE	SUB-FREE	MIDDLING	SUB-MIDDLING	TOTAL	Zn Rec.
LIBERATION in the float feed	62.5	24.6	6.25	6.70	----	100.0
RECOVERY in the Cu-Conc.	12.0	12.1	66.5	37.9	13.7	15.2
RECOVERY in the Zn-Conc.	73.5 (83.5)	46.9 (53.4)	9.13 (27.3)	1.58 (2.54)	49.7 (57.6)	51.9 (61.2)
RECOVERY in the Tailings	14.5	41.1	24.4	60.5	36.6	33.0

a) Whereas 62.5 % of the sphalerite in the feed occurs as free grains, 87.1 % occurs as free plus sub-free grains. This relatively high fraction of 'recoverable' grains of sphalerite indicates a high 'effective' liberation. While 12 % of both the free and sub-free grains are recovered in the Cu-concentrate, a further 14.5 % of the free and 41.1 % of the sub-free grains are rejected to the tailings. Approximately 60 % of the 'recoverable' sphalerite entering the Zn-circuit is recovered in the Zn-concentrate, indicating that the Zn-circuit is not operating efficiently. Because 'recoverable' grains of sphalerite constitute 87.1 % of the sphalerite in the feed, the loss of approximately 30 % of these to the tailings results in a corresponding loss of approximately 25 % of the sphalerite in the feed, and accounts for approximately 80 % of the sphalerite in the tailings.

b) Of the sphalerite in the feed, 6.25 % occurs as middling grains. These are principally recovered in the Cu-concentrate (i.e. 66.5 %), correspond to 3.6 % of the sphalerite in the feed, and account for approximately 25 % of the sphalerite in the Cu-concentrate. A further 24.4 % of the middling grains are rejected to the tailings, which corresponds to 2.1 % of the sphalerite in the feed, and accounts for approximately 5 % of the sphalerite in the tailings. Because 6.25 % of the sphalerite in the feed occurs as middling grains, and of which 91 % is lost to the Cu-concentrate and tailings combined, enhanced liberation and recovery by regrinding these middling grains may be significant (i.e. ≤5 %).

c) Of the 5.91 % sub-middling sphalerite grains in the feed only 0.09 % (i.e. 1.6 %) is recovered in the Zn-concentrate, 2.22 % (i.e. 38 %) in the Cu-concentrate, while 5.16 % (i.e. 61 %) is rejected to the tailings. The sub-middling grains comprise approximately 15 % of the sphalerite in both the Cu-concentrate and tailings. These combined losses of approximately 6 % of the sphalerite in the feed, and corresponding to 98 % of the sub-middling grains, are unrecoverable without recourse to extremely fine regrinding.

d) Of the 13.7 % of the sphalerite recovered in the Cu-concentrate, 44 % occur as free, 18 % as sub-free, 24 % as middling and 15 % as sub-middling grains. The recovery of 'recoverable' grains of sphalerite in the Cu-concentrate is approximately 12 %, which corresponds to 9.5 % of the sphalerite in the feed, and approximately 62 % of the sphalerite in the Cu-concentrate. Thus, 62 % of the sphalerite lost to the Cu-concentrate is recoverable (in the Zn-concentrate), confirming that the sphalerite losses are largely liberation-independent, and due to poor rejection of sphalerite in the Cu-circuit.

8. Whereas 13.7 % of the sphalerite, only 2.19 % of the gangue and 2.23 % of the pyrite in the feed are recovered in the Cu-concentrate. The relatively high rejection of gangue and pyrite

from the Cu-circuit indicates that the sphalerite is not recovered by mechanical entrainment, but rather is due to poor sphalerite rejection in the Cu-circuit.

9. The host particle size distributions of free and sub-free sphalerite, which combined comprise approximately 62, 99 and 75 % of the sphalerite in the Cu- and Zn-concentrates and tailings, show that the 'recoverable' sphalerite recovered in the Cu-concentrate is finer-grained, and that rejected to the tailings is coarser-grained, than that recovered in the Zn-concentrate. However, greater than 85 % of the 'recoverable' sphalerite in each of these products falls within the optimum particle flotation range of 5 to 100 um. Thus, entrainment of 'slimes', and the failure to float 'over-sized' sphalerite, only contribute a minor fraction of these losses. The losses of 'recoverable' sphalerite to the Cu-concentrate are attributed to poor selective flotation of sphalerite, possibly resulting from activation and/or poor conditioning. Preliminary testwork at CANMET indicates that proper conditioning is critical in reducing the sphalerite losses to Trout Lake Cu-concentrate (W. Petruk., pers. comm. 1989). The losses of 'recoverable' grains to the tailings are largely attributed to poor flotation and circuit efficiency in the recovery of grains that fall within routinely 'recoverable' particle liberation and size limits. However, this may merely reflect operation of the Zn-circuit above normal capacity, due to the high Zn head grade.

10. Excluding the 'recoverable' sphalerite lost to the Cu-concentrate, (which if largely 'over-sized', would have been amenable to regrinding) the principal losses of both chalcopyrite and sphalerite are as middling and particularly sub-middling grains. Because of the dominant sub-middling fractions particularly, these grains require extremely fine regrinding (i.e. 80 % - 26 um) to achieve liberation. Furthermore, regrinding will address the loss of 'over-sized' sub-free chalcopyrite, which comprises a significant fraction of the 1.7 % of the chalcopyrite in the feed that is lost as sub-free grains. It is predicted that a maximum of 6 and 10 % improvements in the recoveries of chalcopyrite and sphalerite, respectively might be realized, if extremely fine regrinding can be directed at streams enriched in the middling and sub-middling fractions, specifically.

11. Despite the high Au assay of the feed (i.e. 1.60 ppm), no Au-bearing mineral was observed in any of the products, prohibiting any conclusions on the cause of the high Au losses to the tailings (i.e. 42.0 %).

12. Based on Ag assays and the recoveries of sphalerite in the circuit products, Ag in solid solution in sphalerite accounts for less than 6.5 % of the Ag in the feed. It is inferred that chalcopyrite, pyrite, tetrahedrite, sphalerite and galena are the principal Ag-carriers in the ore.

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Appendix A

RAW MINERAL QUANTITIES DATA

TABLE 1

MINERAL QUANTITIES OF THE MINERALS OF INTEREST IN THE FOUR STALL LAKE END PRODUCTS.

PRODUCT	Gangue	Pyrite	Pyrr.	Cpy.	Sphal.	Asp.	Gal.
			Surface area (1,000 um^2)				
Feed	857.	758.	133.	132.	66.6	1.99	12.5
Cu-Conc.	64.0	45.8	47.0	423.	38.1	0.65	1.92
Zn-Conc.	21.6	27.0	205.	34.4	1550.	0.00	10.4
Tails.	3550.	2120.	665.	32.5	138.	----	16.0

Note: '----' denotes spurious data for arsenopyrite in the tailings.

Appendix B

GRAIN SIZE AND CLASSIFICATION TABLES FOR CHALCOPYRITE, SPHALERITE, GALENA AND PYRITE

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	.388E+04	.389E+04
4.73	0.00	0.00	5.00	7.00	71.0	191.	72.0	146.	33.0	47.0	.953E+04	.618E+04
6.69	0.00	4.00	148.	176.	110.	151.	385.	271.	367.	157.	.884E+04	.981E+04
9.45	0.00	162.	252.	196.	107.	112.	138.	221.	912.	784.	.125E+05	.154E+05
13.3	147.	200.	183.	445.	338.	443.	226.	421.	252.	.348E+04	.141E+05	.203E+05
18.9	479.	468.	385.	683.	534.	784.	572.	0.00	942.	.420E+04	.155E+05	.245E+05
26.6	784.	683.	532.	524.	861.	825.	.113E+04	.121E+04	391.	.294E+04	.196E+05	.198E+05
37.7	526.	381.	268.	0.00	320.	.374E+04	784.	0.00	652.	.363E+04	.659E+04	.168E+05
53.2	386.	496.	0.00	0.00	688.	0.00	0.00	.139E+04	.145E+04	.292E+04	.177E+04	.906E+04
75.2	192.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.293E+04	.312E+04
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.235E+04	.231E+04	.169E+04	.983E+04	.842E+04	.625E+04	.323E+04	.367E+04	.580E+04	.182E+05	.807E+05	.128E+06

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	.467E-02	0.00	0.00	0.00	2.41	2.42
4.73	0.00	0.00	.391E-02	.547E-02	.555E-01	.149	.563E-01	.114	.256E-01	.367E-01	4.32	4.77
6.69	0.00	.313E-02	.116	.138	.863E-01	.118	.301	.212	.687	.123	6.29	7.67
9.45	0.00	.127	.197	.153	.837E-01	.876E-01	.188	.173	.713	.913	9.78	12.0
13.3	.115	.156	.143	.348	.264	.346	.177	.329	.197	2.72	11.1	15.9
18.9	.375	.366	.238	.534	.418	.613	.447	0.00	.736	3.28	12.1	19.1
26.6	.550	.472	.416	.410	.204	.645	.881	.949	.386	2.38	8.31	15.4
37.7	.411	.298	.210	0.00	.250	2.93	.550	0.00	.510	2.84	5.15	13.1
53.2	.240	.388	0.00	0.00	.531	0.00	0.00	1.03	1.14	2.21	1.33	7.88
75.2	.150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.29	2.44
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.04	1.01	1.32	1.59	1.09	4.09	2.53	2.07	3.91	14.2	63.1	100.0

TABLE 1.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	.189E+04	.190E+04
3.35												
0.00	0.00	0.00	0.00	22.0	17.0	26.0	12.0	67.0	25.0	0.00	.326E+04	.343E+04
4.73												
0.00	0.00	0.00	98.0	65.0	62.5	94.0	67.0	71.0	35.0	76.0	.519E+04	.577E+04
6.69												
7.00	190.	101.	63.0	77.0	25.0	98.0	53.0	93.0	44.0	0.00	.749E+04	.824E+04
9.45												
151.	168.	64.0	83.0	140.	0.00	230.	274.	0.00	346.	0.00	.828E+04	.974E+04
13.3												
236.	313.	191.	443.	205.	319.	344.	356.	238.	357.	0.00	.705E+04	.101E+05
18.9												
285.	50.0	0.00	158.	467.	782.	376.	480.	538.	.126E+04	.102E+05	.146E+05	
26.6												
318.	205.	256.	566.	0.00	545.	0.00	933.	.189E+04	.143E+04	.272E+04	.832E+04	
37.7												
377.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.217E+04	0.00	.254E+04	
53.2												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
75.2												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
.137E+04	934.	710.	.140E+04	969.	.179E+04	.113E+04	.229E+04	.282E+04	.568E+04	.461E+05	.652E+05	

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00	0.00	0.00	0.00	0.00	0.00	.920E-02	0.00	0.00	0.00	2.91	2.91	
3.35												
0.00	0.00	0.00	.337E-01	.261E-01	.399E-01	.184E-01	.103	.383E-01	0.00	5.00	5.26	
4.73												
0.00	.123E-01	.150	.997E-01	.959E-01	.144	.103	.109	.537E-01	.117	7.96	8.65	
6.69												
.107E-01	.291	.155	.966E-01	.118	.383E-01	.150	.797E-01	.143	.675E-01	11.5	12.6	
9.45												
.232	.258	.981E-01	.127	.215	0.00	.353	.420	0.00	.531	12.7	14.3	
13.3												
.362	.480	.293	.679	.314	.489	.527	.546	.365	.547	10.8	15.4	
18.9												
.437	.767E-01	0.00	.242	.716	1.20	.577	.736	.825	1.93	15.7	22.4	
26.6												
.488	.314	.393	.868	0.00	.836	0.00	1.52	2.90	2.19	4.17	13.7	
37.7												
.577	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.00	3.90	
53.2												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
75.2												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
106.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
150.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
212.												
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2.11	1.43	1.09	2.15	1.49	2.75	1.74	3.52	4.32	8.71	70.7	100.	

TABLE 2.

Data for the classification and size distribution of free and unliberated SPHALERITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	327.	327.
4.73	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	381.	382.
6.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	513.	513.
9.45	2.00	18.0	19.0	0.00	0.00	25.0	0.00	0.00	0.00	0.00	413.	477.
13.3	30.0	31.0	0.00	87.0	0.00	0.00	0.00	0.00	0.00	0.00	237.	385.
18.9	105.	0.00	71.0	0.00	0.00	148.	196.	0.00	0.00	0.00	182.	704.
26.6	196.	363.	130.	192.	515.	0.00	0.00	0.00	0.00	0.00	0.00	.139E+04
37.7	437.	0.00	0.00	0.00	0.00	542.	562.	0.00	0.00	0.00	0.00	.154E+04
53.2	375.	261.	.149E+04	0.00	0.00	0.00	.264E+04	0.00	0.00	.156E+04	0.00	.633E+04
75.2	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.115E+04	673.	.171E+04	279.	515.	715.	.348E+04	0.00	0.00	.156E+04	.205E+04	.121E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.71	2.71
4.73	.829E-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.16	3.17
6.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.26	4.26
9.45	.166E-01	.149	.158	0.00	0.00	.207	0.00	0.00	0.00	0.00	3.42	3.96
13.3	.249	.857	0.00	.722	0.00	0.00	0.00	0.00	0.00	0.00	1.97	3.19
18.9	.871	0.00	.589	0.00	0.00	1.23	1.64	0.00	0.00	0.00	1.51	5.84
26.6	1.57	3.01	1.08	1.59	4.27	0.00	0.00	0.00	0.00	0.00	0.00	11.5
37.7	3.62	0.00	0.00	0.00	0.00	4.50	4.66	0.00	0.00	0.00	0.00	12.8
53.2	3.11	2.16	12.3	0.00	0.00	0.00	21.9	0.00	0.00	13.0	0.00	52.5
75.2	.829E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.829E-01
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.54	5.58	14.2	2.31	4.27	5.93	28.2	0.00	0.00	13.0	17.6	100.

TABLE 3.

Data for the classification and size distribution of free and unliberated GALENA in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	7.00	21.0	8.00	0.00	.744E+04	.748E+04
4.73	0.00	0.00	0.00	0.00	9.00	28.0	123.	113.	132.	35.0	.184E+05	.188E+05
6.69	0.00	0.00	34.0	16.4	30.0	62.2	83.6	177.	372.	522.	.362E+05	.375E+05
9.45	11.0	66.0	86.0	115.	0.00	113.	58.1	396.	298.	.179E+04	.613E+05	.643E+05
13.3	291.	294.	343.	484.	193.	95.0	0.00	0.00	835.	.400E+04	.872E+05	.936E+05
18.9	492.	543.	887.	.103E+04	.136E+04	.136E+04	.130E+04	868.	.169E+04	.816E+04	.103E+06	.121E+06
26.6	487.	783.	847.	.179E+04	.216E+04	.307E+04	.614E+04	.791E+04	.357E+04	.124E+05	.109E+06	.1-0E+06
37.7	799.	104.	.114E+04	578.	.271E+04	.112E+04	.619E+04	.588E+04	.224E+05	.150E+05	.783E+05	.134E+06
53.2	767.	172.	973.	0.00	.267E+04	.160E+04	.206E+04	.126E+04	.922E+04	.190E+05	.289E+05	.667E+05
75.2	89.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.158E+05	.152E+05	.3:1E+05
106.	0.00	0.00	0.00	0.00	0.00	0.00	.792E+04	0.00	0.00	.557E+04	0.00	.135E+05
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.285E+04	.197E+04	.423E+04	.481E+04	.974E+04	.745E+04	.239E+05	.165E+05	.385E+05	.822E+05	.545E+06	.737E+06

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	.350E-03	.285E-02	.109E-02	0.00	1.01	1.02
4.73	0.00	0.00	0.00	0.00	.122E-02	.300E-02	.167E-01	.153E-01	.179E-01	.475E-02	2.49	2.55
6.69	0.00	0.00	.462E-02	.222E-02	.407E-02	.844E-02	.114E-01	.240E-01	.505E-01	.709E-01	4.91	5.09
9.45	.149E-02	.896E-02	.117E-01	.156E-01	0.00	.153E-01	.789E-02	.538E-01	.405E-01	.243	8.32	8.72
13.3	.273E-01	.399E-01	.466E-01	.657E-01	.262E-01	.129E-01	0.00	0.00	.113	.543	11.8	12.7
18.9	.668E-01	.737E-01	.110	.140	.266	.185	.177	.118	.229	1.11	14.0	16.5
26.6	.661E-01	.107	.115	.243	.293	.417	.834	1.07	.484	1.68	14.8	20.1
37.7	.100	.141E-01	.155	.785E-01	.368	.152	.840	.787	3.04	2.84	10.6	18.2
53.2	.104	.233E-01	.132	0.00	.363	.217	.279	.171	1.25	2.58	3.93	9.05
75.2	.121E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	2.07	4.23
106.	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00	.756	0.00	1.83
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.386	.267	.574	.544	1.32	1.01	3.24	2.25	5.23	11.2	74.0	100.0

TABLE 4.

Data for the classification and size distribution of free and unliberated PYRITE in the feed. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.213E+04	.213E+04
4.73	0.00	0.00	6.00	14.0	15.0	46.0	24.0	75.0	16.0	0.00	.525E+04	.545E+04
6.69	0.00	15.0	101.	116.	107.	218.	209.	189.	305.	72.0	.101E+05	.115E+05
9.45	13.0	152.	250.	207.	143.	371.	825.	.126E+04	953.	324.	.170E+05	.215E+05
13.3	32.0	318.	282.	320.	582.	331.	981.	.120E+04	.236E+04	.203E+04	.250E+05	.341E+05
18.9	192.	487.	290.	376.	770.	841.	662.	915.	.539E+04	.121E+05	.310E+05	.530E+05
26.6	278.	329.	422.	521.	.107E+04	.144E+04	.164E+04	.280E+04	.424E+04	.223E+05	.427E+05	.777E+05
37.7	312.	386.	324.	0.00	.178E+04	.107E+04	.266E+04	.213E+04	.475E+04	.310E+05	.225E+05	.669E+05
53.2	23.0	585.	0.00	0.00	797.	.109E+04	0.00	.116E+04	.106E+05	.571E+05	.187E+05	.900E+05
75.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.299E+05	0.00	.299E+05
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.233E+05	.749E+04	.308E+05
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	919.	.213E+04	.168E+04	.155E+04	.526E+04	.541E+04	.700E+04	.974E+04	.292E+05	.178E+06	.182E+06	.423E+06

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.50-	.52-
4.73	0.00	0.00	.142E-02	.331E-02	.355E-02	.109E-01	.568E-02	.177E-01	.378E-02	0.00	1.24	1.23
6.69	0.00	.355E-02	.239E-01	.274E-01	.253E-01	.515E-01	.494E-01	.447E-01	.721E-01	.170E-01	2.39	2.71
9.45	.347E-02	.359E-01	.591E-01	.489E-01	.338E-01	.877E-01	.195	.299	.225	.766E-01	4.02	5.08
13.3	.218E-01	.752E-01	.667E-01	.757E-01	.138	.783E-01	.232	.284	.700	.481	5.91	8.06
18.9	.454E-01	.115	.686E-01	.889E-01	.182	.199	.157	.216	1.27	2.85	7.34	12.5
26.6	.657E-01	.778E-01	.998E-01	.123	.252	.340	.389	.661	1.00	5.27	10.1	18.4
37.7	.738E-01	.724E-01	.766E-01	0.00	.420	.252	.629	.505	1.12	7.34	5.33	15.8
53.2	.544E-02	.124	0.00	0.00	.188	.259	0.00	.274	2.51	13.5	4.42	21.3
75.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.07	0.00	7.07
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.51	1.77	7.28
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.215	.504	.396	.367	1.24	1.28	1.66	2.38	6.91	42.1	43.0	100.

TABLE 5.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	653.	653.
4.73	0.00	0.00	0.00	15.0	31.0	28.0	19.0	12.0	0.00	0.00	.102E+04	.113E+04
6.69	0.00	6.00	104.	96.0	13.0	42.0	19.0	73.0	29.0	0.00	.183E+04	.222E+04
9.45	6.00	107.	54.0	175.	222.	119.	159.	101.	0.00	52.0	.179E+04	.287E+04
13.3	102.	212.	159.	81.0	104.	67.0	443.	0.00	374.	258.	.351E+04	.531E+04
18.9	342.	251.	243.	104.	100.0	296.	421.	544.	0.00	.151E+04	.336E+04	.717E+04
26.6	456.	444.	360.	274.	912.	326.	570.	0.00	0.00	775.	.218E+04	.638E+04
37.7	585.	444.	252.	451.	0.00	412.	0.00	.120E+04	631.	0.00	.204E+04	.602E+04
53.2	565.	718.	0.00	622.	0.00	.191E+04	0.00	0.00	0.00	.143E+04	0.00	.524E+04
75.2	138.	924.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.106E+04
106.	166.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	166.
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.236E+04	.311E+04	.117E+04	.102E+04	.138E+04	.320E+04	.163E+04	.201E+04	.103E+04	.403E+04	.164E+05	.381E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71	1.71
4.73	0.00	0.00	0.00	.393E-01	.813E-01	.734E-01	.498E-01	.315E-01	0.00	0.00	2.68	2.96
6.69	0.00	.157E-01	.273	.252	.341E-01	.110	.498E-01	.131	.761E-01	0.00	4.81	5.81
9.45	.157E-01	.281	.142	.459	.582	.312	.417	.475	0.00	.136	4.71	7.53
13.3	.268	.556	.417	.212	.273	.176	1.16	0.00	.981	.677	9.20	13.9
18.9	.897	.658	.637	.273	.262	.776	1.10	1.43	0.00	3.96	8.81	18.8
26.6	1.20	1.16	.944	.719	2.39	.855	1.49	0.00	0.00	2.03	5.72	16.5
37.7	1.53	1.16	.661	1.18	0.00	1.08	0.00	3.14	1.65	0.00	5.36	15.8
53.2	1.48	1.88	0.00	1.63	0.00	5.00	0.00	0.00	0.00	3.75	0.00	13.7
75.2	.362	2.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.79
106.	.435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.435
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.19	8.15	3.07	4.77	3.62	8.38	4.28	5.27	2.71	10.6	43.0	100.

TABLE 6.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.0	31.0
4.73	1.000	4.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	19.0	33.0
6.69	2.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.0	41.0
9.45	4.00	0.00	16.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.	145.
13.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.9	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	156.	0.00	0.00	162.
26.6	38.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	548.	0.00	0.00	586.
37.7	28.0	0.00	0.00	0.00	0.00	542.	0.00	0.00	0.00	0.00	0.00	570.
53.2	26.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.0
75.2	1.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000
106.	248.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	248.
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	352.	7.00	16.0	0.00	9.00	542.	0.00	0.00	706.	0.00	211.	.184E+04

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68	1.68
4.73	.543E-01	.217	0.00	0.00	.488	0.00	0.00	0.00	0.00	0.00	1.03	1.79
6.69	.109	.163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95	2.22
9.45	.217	0.00	.866	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.78	7.87
13.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.9	.217	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.57	0.00	0.00	8.79
26.6	2.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.7	0.00	0.00	31.8
37.7	1.52	0.00	0.00	0.00	0.00	29.4	0.00	0.00	0.00	0.00	0.00	30.9
53.2	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41
75.2	.543E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.543E-01
106.	13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.5
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	19.1	.380	.866	0.00	.488	29.4	0.00	0.00	38.3	0.00	11.4	100.0

TABLE 7.

Data for the classification and size distribution of free and unliberated GALENA in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	346.	346.
4.73	0.00	0.00	0.00	0.00	18.0	15.0	0.00	0.00	0.00	0.00	863.	896.
6.69	0.00	7.00	54.0	47.0	29.0	28.0	24.0	0.00	0.00	38.0	.169E+04	.192E+04
9.45	34.0	86.0	26.0	71.0	21.0	46.0	42.0	159.	240.	48.0	.279E+04	.356E+04
13.3	34.0	103.	22.0	58.0	0.00	0.00	0.00	744.	638.	382.	.354E+04	.552E+04
18.9	60.0	106.	129.	254.	0.00	0.00	159.	.127E+04	573.	.170E+04	.461E+04	.887E+04
26.6	140.	269.	272.	0.00	0.00	254.	341.	714.	.155E+04	.459E+04	.555E+04	.137E+05
37.7	101.	98.0	0.00	0.00	0.00	505.	0.00	.155E+04	.144E+04	702.	.310E+04	.749E+04
53.2	201.	196.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.143E+04	.167E+04	.349E+04
75.2	33.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.0
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	623.	857.	503.	438.	68.0	848.	566.	.444E+04	.443E+04	.889E+04	.242E+05	.458E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.755	.755
4.73	0.00	0.00	0.00	.175E-01	.393E-01	.327E-01	0.00	0.00	0.00	0.00	1.88	1.97
6.69	0.00	.153E-01	.118	.103	.633E-01	.611E-01	.524E-01	0.00	0.00	.829E-01	3.69	4.13
9.45	.742E-01	.188	.567E-01	.155	.458E-01	.100	.917E-01	.347	.524	.105	6.09	7.76
13.3	.742E-01	.225	.480E-01	.127	0.00	0.00	0.00	1.62	1.38	.834	7.73	12.0
18.9	.175	.231	.282	.554	0.00	0.00	.347	2.76	1.25	3.70	10.1	19.4
26.6	.386	.587	.594	0.00	0.00	.554	.744	1.56	3.38	10.0	12.1	29.3
37.7	.220	.196	0.00	0.00	0.00	1.10	0.00	3.39	3.14	1.53	6.78	16.4
53.2	.439	.428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	3.64	7.63
75.2	.720E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.720E-01
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.36	1.87	1.10	.956	.148	1.85	1.24	9.68	9.67	19.4	52.7	100.

TABLE 8.

Data for the classification and size distribution of free and unliberated PYRITE in the Cu-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	93.0	93.0
4.73	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	14.0	0.00	69.0	90.0
6.69	0.00	6.00	19.0	23.0	25.0	17.0	0.00	0.00	0.00	0.00	0.00	90.0
9.45	35.0	172.	17.0	0.00	0.00	0.00	0.00	0.00	45.0	0.00	116.	387.
13.3	146.	136.	24.0	56.0	0.00	0.00	0.00	0.00	0.00	0.00	123.	485.
18.9	451.	183.	79.0	92.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	805.
26.6	.112E+04	335.	105.	135.	0.00	391.	0.00	0.00	0.00	543.	560.	.318E+04
37.7	.143E+04	345.	222.	319.	0.00	0.00	0.00	0.00	0.00	.129E+04	0.00	.361E+04
53.2	.196E+04	785.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.263E+04	0.00	.538E+04
75.2	877.	0.00	0.00	0.00	0.00	0.00	.255E+04	0.00	0.00	.303E+04	0.00	.646E+04
106.	111.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.134E+05	0.00	.135E+05
150.	21.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.0
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.615E+04	.196E+04	466.	625.	32.0	408.	.256E+04	0.00	59.0	.209E+05	963.	.341E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.273	.273
4.73	0.00	0.00	0.00	0.00	.205E-01	0.00	.234E-01	0.00	.410E-01	0.00	.202	.287
6.69	0.00	.176E-01	.557E-01	.674E-01	.733E-01	.498E-01	0.00	0.00	0.00	0.00	0.00	.264
9.45	.103	.504	.498E-01	0.00	0.00	0.00	0.00	0.00	.132	0.00	.346	1.13
13.3	.428	.399	.703E-01	.164	0.00	0.00	0.00	0.00	0.00	0.00	.360	1.42
18.9	1.32	.536	.232	.270	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36
26.6	3.27	.982	.308	.396	0.00	1.15	0.00	0.00	0.00	1.59	1.64	9.33
37.7	4.20	1.01	.651	.935	0.00	0.00	0.00	0.00	0.00	3.77	0.00	10.6
53.2	5.76	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.72	0.00	15.8
75.2	2.57	0.00	0.00	0.00	0.00	0.00	7.47	0.00	0.00	8.86	0.00	18.9
106.	.325	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.3	0.00	39.6
150.	.615E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.615E-01
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	16.0	5.75	1.37	1.83	.938E-01	1.28	7.49	0.00	.173	61.2	2.82	100.

TABLE 9.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.478E+04	.478E+04
4.73	0.00	0.00	5.00	0.00	25.0	24.0	22.0	0.00	16.0	0.00	.128E+05	.129E+05
6.69	0.00	7.00	50.0	81.0	137.	119.	354.	150.	67.0	0.00	.256E+05	.265E+05
9.45	0.00	10.00	59.0	112.	147.	427.	556.	608.	.113E+04	817.	.476E+05	.515E+05
13.3	19.0	173.	47.0	85.0	149.	422.	590.	.135E+04	.383E+04	.381E+04	.981E+05	.108E+06
18.9	55.0	199.	139.	353.	126.	906.	.146E+04	.141E+04	.733E+04	.192E+05	.153E+06	.184E+06
26.6	327.	130.	111.	134.	578.	.132E+04	.150E+04	.150E+04	.762E+04	.369E+05	.229E+06	.279E+06
37.7	456.	0.00	253.	577.	482.	.121E+04	.163E+04	.266E+04	.367E+04	.956E+05	.242E+06	.349E+06
53.2	0.00	0.00	0.00	0.00	589.	0.00	0.00	.120E+04	.560E+04	.120E+06	.192E+06	.319E+06
75.2	165.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.763E+05	.616E+05	.138E+06
106.	489.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.182E+05	.631E+04	.250E+05
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.141E+05	0.00	.141E+05
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.151E+04	519.	664.	.134E+04	.223E+04	.442E+04	.619E+04	.890E+04	.285E+05	.385E+06	.107E+07	.151E+07

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.316	.316
4.73	0.00	0.00	.331E-03	0.00	.165E-02	.159E-02	.146E-02	0.00	.106E-02	0.00	.844	.850
6.69	0.00	.463E-03	.331E-02	.536E-02	.986E-02	.787E-02	.234E-01	.992E-02	.443E-02	0.00	1.69	1.76
9.45	0.00	.661E-03	.398E-02	.741E-02	.972E-02	.262E-01	.368E-01	.402E-01	.747E-01	.540E-01	3.15	3.40
13.3	.126E-02	.114E-01	.311E-02	.562E-02	.986E-02	.279E-01	.390E-01	.895E-01	.201	.252	6.49	7.13
18.9	.364E-02	.132E-01	.919E-02	.233E-01	.833E-02	.599E-01	.965E-01	.934E-01	.485	1.27	10.1	12.2
26.6	.216E-01	.860E-02	.734E-02	.886E-02	.382E-01	.872E-01	.105	.995E-01	.584	2.44	15.2	18.5
37.7	.298E-01	0.00	.167E-01	.382E-01	.319E-01	.798E-01	.108	.176	.243	6.33	16.0	23.1
53.2	0.00	0.00	0.00	0.00	.398E-01	0.00	0.00	.796E-01	.371	7.91	12.7	21.1
75.2	.109E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.05	4.07	9.13
106.	.323E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	.418	1.65
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.934	0.00	.934
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.995E-01	.343E-01	.439E-01	.886E-01	.146	.293	.489	.588	1.88	25.4	71.0	100.

TABLE 10.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	145.	145.
4.73	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	834.	854.
6.69	0.00	0.00	0.00	12.0	0.00	0.00	0.00	0.00	0.00	0.00	451.	463.
9.45	0.00	0.00	0.00	23.0	37.0	0.00	0.00	0.00	0.00	0.00	618.	658.
13.3	3.00	24.0	0.00	0.00	0.00	73.0	0.00	0.00	386.	0.00	.193E+04	.156E+04
18.9	44.0	23.0	73.0	0.00	0.00	0.00	0.00	0.00	0.00	188.	582.	982.
26.6	2.00	167.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	379.	665.	.121E+04
37.7	134.	0.00	0.00	486.	0.00	0.00	0.00	0.00	0.00	733.	0.00	.107E+04
53.2	291.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	291.
75.2	339.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.394E+04	0.00	.338E+04
106.	81.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.0
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	894.	214.	77.0	441.	65.0	81.0	0.00	0.00	386.	.433E+04	.379E+04	.108E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42	1.42
4.73	0.00	0.00	.392E-01	0.00	.784E-01	.784E-01	0.00	0.00	0.00	0.00	2.29	2.49
6.69	0.00	0.00	0.00	.118	0.00	0.00	0.00	0.00	0.00	0.00	4.42	4.54
9.45	0.00	0.00	0.00	.226	.369	0.00	0.00	0.00	0.00	0.00	6.06	6.64
13.3	.294E-01	.235	0.00	0.00	0.00	.716	0.00	0.00	3.80	0.00	10.7	14.7
18.9	.431	.226	.716	0.00	0.00	0.00	0.00	0.00	0.00	1.76	5.71	8.84
26.6	.196E-01	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.72	6.52	11.9
37.7	1.31	0.00	0.00	3.98	0.00	0.00	0.00	0.00	0.00	7.19	0.00	12.5
53.2	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.85
75.2	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.8	0.00	33.1
106.	.794	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.794
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.77	2.10	.755	4.32	.637	.794	0.00	0.00	3.80	42.5	37.2	100.

TABLE 11.

Data for the classification and size distribution of free and unliberated GALENA in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	72.0	72.0
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.0	130.	150.
6.69	0.00	0.00	11.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.	137.
9.45	7.00	19.0	16.0	16.0	27.0	0.00	32.0	77.0	111.	0.00	446.	751.
13.3	10.00	34.0	56.0	41.0	71.0	67.0	0.00	166.	385.	0.00	673.	.151E+04
18.9	125.	95.0	0.00	78.0	139.	181.	560.	0.00	253.	.119E+04	.146E+04	.498E+04
26.6	168.	282.	0.00	341.	542.	463.	0.00	378.	836.	.215E+04	.205E+04	.715E+04
37.7	212.	0.00	288.	811.	0.00	0.00	536.	0.00	817.	.463E+04	.210E+04	.960E+04
53.2	197.	316.	0.00	0.00	0.00	820.	0.00	0.00	0.00	.162E+04	0.00	.287E+04
75.2	43.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.0
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	692.	946.	371.	.129E+04	779.	.153E+04	.113E+04	623.	.240E+04	.982E+04	.706E+04	.264E+05

B.

3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.273	.273
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.759E-01	.493	.569
6.69	0.00	0.00	.417E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.478	.520
9.45	.266E-01	.721E-01	.607E-01	.607E-01	.102	0.00	.121	.292	.421	0.00	1.69	2.85
13.3	.379E-01	.129	.212	.156	.269	.254	0.00	.637	1.46	0.00	2.58	5.73
18.9	.474	.360	0.00	.296	.527	.687	2.12	0.00	.960	4.50	5.56	15.5
26.6	.713	.766	0.00	1.29	2.06	1.76	0.00	1.43	3.17	8.17	7.76	27.1
37.7	.804	0.00	1.93	3.06	0.00	0.00	2.04	0.00	3.10	10.3	7.97	36.4
53.2	.498	1.20	0.00	0.00	0.00	3.11	0.00	0.00	0.00	6.16	0.00	10.9
75.2	.163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.163
106.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.63	2.53	1.41	4.88	2.96	5.81	4.29	2.36	9.11	37.2	26.8	100.0

TABLE 12.

Data for the classification and size distribution of free and unliberated PYRITE in the Zn-concentrate. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.6	41.6
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	318.	318.
6.69	0.00	0.00	0.00	9.09	23.6	34.5	0.00	52.7	0.00	0.00	58.1	178.
9.45	0.00	0.00	27.3	40.0	38.2	40.0	0.00	0.00	0.00	0.00	218.	363.
13.3	10.9	63.6	20.0	0.00	36.3	134.	0.00	0.00	0.00	0.00	0.00	265.
18.9	49.1	52.7	0.00	0.00	109.	118.	0.00	0.00	0.00	0.00	0.00	329.
26.6	234.	0.00	167.	0.00	0.00	0.00	0.00	462.	0.00	0.00	0.00	863.
37.7	587.	213.	216.	0.00	449.	0.00	0.00	0.00	0.00	0.00	0.00	.146E+04
53.2	485.	174.	0.00	0.00	958.	0.00	.156E+04	0.00	0.00	0.00	0.00	.318E+04
75.2	567.	0.00	0.00	0.00	0.00	0.00	0.00	.263E+04	0.00	0.00	0.00	.320E+04
106.	198.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	198.
150.	422.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	422.
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.110E+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.110E+05
	.136E+05	583.	431.	49.1	.161E+04	327.	.156E+04	.314E+04	0.00	0.00	636.	.218E+05

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.191	.191
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.46	1.46
6.69	0.00	0.00	0.00	.416E-01	.108	.158	0.00	.241	0.00	0.00	.266	.816
9.45	0.00	0.00	.125	.103	.175	.183	0.00	0.00	0.00	0.00	.999	1.67
13.3	.500E-01	.291	.916E-01	0.00	.167	.616	0.00	0.00	0.00	0.00	0.00	1.22
18.9	.225	.241	0.00	0.00	.500	.541	0.00	0.00	0.00	0.00	0.00	1.51
26.6	1.07	0.00	.766	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	3.95
37.7	2.69	.974	.991	0.00	2.06	0.00	0.00	0.00	0.00	0.00	0.00	6.71
53.2	2.22	.799	0.00	0.00	4.39	0.00	7.15	0.00	0.00	0.00	0.00	14.6
75.2	2.60	0.00	0.00	0.00	0.00	0.00	0.00	12.0	0.00	0.00	0.00	14.6
106.	.908	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.908
150.	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.93
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.4
	62.1	2.31	1.97	.225	7.39	1.50	7.15	14.4	0.00	0.00	2.91	100.0

TABLE 13.

Data for the classification and size distribution of free and unliberated CHALCOPYRITE in the Tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.4	65.4
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	769.	769.
6.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.114E+04	.114E+04
9.45	0.00	0.00	38.2	0.00	20.0	0.00	0.00	50.9	0.00	0.00	.185E+04	.196E+04
13.3	0.00	0.00	25.4	0.00	0.00	49.1	72.7	0.00	253.	169.	.143E+04	.200E+04
18.9	32.7	0.00	65.4	69.0	0.00	0.00	0.00	0.00	189.	0.00	.346E+04	.381E+04
26.6	125.	0.00	180.	200.	0.00	0.00	273.	0.00	0.00	414.	.365E+04	.484E+04
37.7	154.	458.	518.	0.00	343.	0.00	0.00	796.	0.00	.337E+04	.445E+04	.101E+05
53.2	912.	825.	0.00	0.00	881.	0.00	0.00	0.00	0.00	.911E+04	.424E+04	.159E+05
75.2	432.	0.00	0.00	0.00	0.00	.289E+04	0.00	0.00	0.00	.852E+04	.351E+04	.146E+05
106.	47.2	876.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	923.
150.	65.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.138E+05	0.00	.139E+05
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	.329E+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.329E+05
	.177E+04	.351E+05	827.	269.	.116E+04	.214E+04	345.	847.	442.	.354E+05	.246E+05	.103E+06

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.636E-01	.636E-01
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.747	.747
6.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	1.11
9.45	0.00	0.00	.371E-01	0.00	.194E-01	0.00	0.00	.495E-01	0.00	0.00	1.79	1.90
13.3	0.00	0.00	.247E-01	0.00	0.00	.477E-01	.706E-01	0.00	.246	.164	1.39	1.95
18.9	.318E-01	0.00	.636E-01	.671E-01	0.00	0.00	0.00	0.00	.184	0.00	3.36	3.71
26.6	.122	0.00	.175	.194	0.00	0.00	.265	0.00	0.00	.403	3.55	4.71
37.7	.150	.445	.503	0.00	.334	0.00	0.00	.774	0.00	3.28	4.32	9.81
53.2	.887	.802	0.00	0.00	.779	0.00	0.00	0.00	0.00	8.66	4.12	15.4
75.2	.420	0.00	0.00	0.00	0.00	2.93	0.00	0.00	0.00	8.28	3.41	14.1
106.	.459E-01	.851	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.897
150.	.636E-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.4	0.00	13.5
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	32.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.0
	1.72	34.1	.804	.261	1.13	2.08	.336	.823	.429	34.4	23.9	100.

TABLE 14.

Data for the classification and size distribution of free and unliberated SPHALERITE in the Tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	0.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00 3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	176.	176.
0.00 4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	325.	325.
5.45 6.69	3.63	0.00	0.00	20.0	0.00	0.00	0.00	0.00	0.00	0.00	205.	234.
1.82 9.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	649.	651.
5.45 13.3	61.8	41.8	0.00	52.7	76.3	69.0	0.00	0.00	0.00	0.00	647.	954.
27.3 18.9	27.3	0.00	80.0	0.00	0.00	0.00	0.00	0.00	0.00	311.	193.	638.
69.0 26.6	0.00	122.	229.	169.	0.00	0.00	0.00	0.00	0.00	0.00	561.	.115E+04
122. 37.7	187.	182.	0.00	0.00	0.00	0.00	0.00	.104E+04	0.00	0.00	.110E+04	.250E+04
21.8 53.2	385.	591.	736.	0.00	865.	0.00	0.00	0.00	0.00	0.00	0.00	.252E+04
294. 75.2	549.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	843.
245. 106.	.140E+04	.389E+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.553E+04
16.4 150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.4
0.00 212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
889.	.247E+04	.482E+04	.104E+04	242.	941.	69.0	.104E+04	0.00	311.	.386E+04	.156E+05	

B.

	0.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
0.00 3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	1.13
0.00 4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	2.08
.349E-01 6.69	.233E-01	0.00	0.00	.126	0.00	0.00	0.00	0.00	0.00	0.00	1.32	1.50
.116E-01 9.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.16	4.17
.349E-01 13.3	.396	.268	0.00	.338	.489	.442	0.00	0.00	0.00	0.00	4.14	6.11
.175 18.9	.175	0.00	.512	0.00	0.00	0.00	0.00	0.00	0.00	1.99	1.23	4.09
.442 86.6	0.00	.780	1.47	1.06	0.00	0.00	0.00	0.00	0.00	0.00	3.60	7.37
.780 37.7	.815	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.06	16.5
.140 53.2	1.96	3.76	4.71	0.00	5.54	0.00	0.00	0.00	0.00	0.00	0.00	16.1
1.89 75.2	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40
1.57 106.	8.94	24.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.4
.105 150.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.105
0.00 212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.18	15.8	38.9	6.69	1.55	6.03	.442	6.68	0.00	1.99	24.7	100.	

TABLE 15.

Data for the classification and size distribution of free and unliberated GALENA in the Tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

A.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	363.	363.
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.4	16.4	0.00	.132E+05	.132E+05
6.69	0.00	0.00	29.1	58.1	70.9	96.3	32.7	76.3	0.00	56.3	.278E+05	.282E+05
9.45	0.00	9.09	114.	63.6	102.	371.	362.	220.	96.3	198.	.499E+05	.515E+05
13.3	41.8	213.	449.	362.	420.	623.	901.	.102E+04	894.	.148E+04	.800E+05	.944E+05
18.9	231.	714.	149.	276.	616.	.117E+04	.129E+04	.215E+04	.398E+04	.484E+04	.142E+06	.157E+06
26.6	696.	636.	943.	.118E+04	.147E+04	752.	.226E+04	.377E+04	.711E+04	.144E+05	.231E+06	.264E+06
37.7	670.	527.	.217E+04	.107E+04	.134E+04	.364E+04	.505E+04	.753E+04	.944E+04	.480E+05	.271E+06	.351E+06
53.2	.138E+04	.112E+04	.228E+04	.103E+04	.460E+04	.527E+04	.639E+04	.103E+05	.229E+05	.124E+06	.325E+06	.504E+06
75.2	.125E+04	.250E+04	0.00	0.00	0.00	0.00	.218E+04	.505E+04	.144E+05	.151E+06	.207E+06	.384E+06
106.	.114E+04	778.	.133E+04	0.00	0.00	0.00	0.00	.570E+04	.269E+05	.975E+05	.367E+05	.170E+06
150.	160.	0.00	0.00	0.00	0.00	0.00	.711E+04	0.00	0.00	.631E+05	0.00	.704E+05
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.183E+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.183E+05
	.238E+05	.650E+04	.746E+04	.484E+04	.870E+04	.119E+05	.256E+05	.358E+05	.858E+05	.504E+06	.139E+07	.211E+07

B.

	9.99	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0		
3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.173E-01	.173E-01
4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.777E-03	.777E-03	0.00	.626	.627
6.69	0.00	0.00	.138E-02	.276E-02	.337E-02	.457E-02	.155E-02	.363E-02	0.00	.268E-02	1.32	1.34
9.45	0.00	.432E-03	.544E-02	.302E-02	.863E-02	.176E-01	.172E-01	.184E-01	.457E-02	.941E-02	2.37	2.44
13.3	.199E-02	.101E-01	.213E-01	.172E-01	.199E-01	.296E-01	.428E-01	.485E-01	.425E-01	.705E-01	4.18	4.49
18.9	.110E-01	.339E-01	.700E-02	.131E-01	.293E-01	.557E-01	.614E-01	.102	.189	.192	6.75	7.45
26.6	.331E-01	.302E-01	.440E-01	.561E-01	.699E-01	.357E-01	.107	.179	.338	.686	11.0	12.5
37.7	.322E-01	.250E-01	.103	.510E-01	.635E-01	.173	.240	.358	.448	2.28	12.9	16.7
53.2	.618E-01	.533E-01	.108	.489E-01	.219	.250	.303	.488	1.09	5.89	15.4	23.9
75.2	.596E-01	.119	0.00	0.00	0.00	0.00	.103	.240	.686	7.17	9.84	18.2
106.	.543E-01	.369E-01	.631E-01	0.00	0.00	0.00	0.00	.271	1.28	4.63	1.74	8.08
150.	.768E-02	0.00	0.00	0.00	0.00	0.00	.338	0.00	0.00	3.00	0.00	3.34
212.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	.871	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.871
	1.13	.309	.354	.192	.413	.566	1.22	1.70	4.07	23.9	66.1	100.0

TABLE 16.

Data for the classification and size distribution of free and unliberated PYRITE in the Tailings. The top row gives the classification; the bottom row gives the summary data for the classification; the left column gives the host particle sizes; the second column from the right gives the host particle size distribution for free grains; the right column gives the summary host particle size distributions. Part A presents the raw surface area data, and Part B presents the data in area percent.

Appendix C

RAW MINERAL ASSOCIATION DATA

TABLE 1

MINERAL ASSOCIATIONS OF CHALCOPYRITE IN THE FOUR STALL LAKE END PRODUCTS.
DATA PRESENTED AS SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Zn-Conc.	Tails.
FREE	78700.	179000.	963.	636.
BINARY				
Cpy + Py	1240.	5550.	9.	0.
Cpy + Gan	3590.	79500.	4260.	362.
Cpy + Sph	19700.	34000.	5800.	3340.
Cpy + Gal	18.	730.	0.	0.
TERNARY				
Cpy + Py + Other	7060.	33400.	732.	11900.
Cpy + Gan + Other	10500.	89500.	21000.	15700.
Cpy + Sph + Other	5170.	78800.	19300.	13500.
Cpy + Gal + Other	1470.	18500.	8660.	970.
Cpy + All Other	24600.	124000.	23100.	17500.

TABLE 2

ADJUSTED MINERAL ASSOCIATIONS OF CHALCOPYRITE IN THE FOUR STALL LAKE END PRODUCTS.

DATA PRESENTED AS MODAL FRACTIONS OF THE ADJUSTED Cu ASSAY.

PRODUCT	ADJUSTED Cu Assay	Free Cpy	Cpy+Py	Cpy+Gan	Cpy+Sph	Cpy+Gal	Ternary Cpy
Feed	2.39	1.21	0.03	0.08	0.24	0.01	0.57
Cu-Conc.	22.5	12.4	0.18	0.70	2.12	0.04	4.34
Zn-Conc.	0.81	0.02	0.01	0.10	0.14	0.01	0.55
Tails.	0.21	0.01	0.01	0.01	0.03	0.01	0.16

TABLE 3

MINERAL ASSOCIATIONS OF SPHALERITE IN THE FOUR STALL LAKE END PRODUCTS.

DATA IN SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Zn-Conc.	Tails.
FREE	45000.	16400.	1040000.	21100.
BINARY				
Sph + Py	3060.	8.	8670.	2500.
Sph + Gan	4710.	1940.	135000.	9780.
Sph + Cpy	7820.	8370.	175000.	10800.
Sph + Gal	680.	52.	14800.	18.
TERNARY				
Sph + Py + Other	1180.	2030.	14500.	50800.
Sph + Gan + Other	2540.	8780.	64400.	52800.
Sph + Cpy + Other	3000.	10800.	94600.	53500.
Sph + Gal + Other	222.	415.	17200.	80.
Sph + All Other	3960.	11400.	142000.	58800.

TABLE 4

ADJUSTED MINERAL ASSOCIATIONS OF SPHALERITE IN THE FOUR STALL LAKE END PRODUCTS.

DATA PRESENTED AS MODAL FRACTIONS OF THE ADJUSTED Zn ASSAY.

PRODUCT	ADJUSTED Zn Assay	Free Sph	Sph+Py	Sph+Gan	Sph+Cpy	Sph+Gal	Ternary Sph
Feed	2.50	1.38	0.03	0.20	0.32	0.02	0.41
Cu-Conc.	3.90	1.71	0.01	0.20	0.84	0.01	1.00
Zn-Conc.	51.0	39.9	0.30	4.21	5.77	0.53	4.19
Tails.	0.94	0.23	0.02	0.09	0.10	0.01	0.23

TABLE 5

MINERAL ASSOCIATIONS OF GALENA IN THE FOUR STALL LAKE END PRODUCTS.

DATA PRESENTED AS SURFACE AREA (um^2).

PARTICLE TYPE	Feed.	Cu-Conc.	Zn-Conc.	Tails.
FREE	2490.	290.	3920.	4280.
BINARY				
Gal + Py	254.	0.	0.	134.
Gal + Gan	2560.	8.	198.	5790.
Gal + Sph	31.	1.	4920.	311.
Gal + Cpy	1.	714.	0.	0.
TERNARY				
Gal + Py + Other	5970.	555.	11.	2160.
Gal + Gan + Other	4650.	853.	1090.	5400.
Gal + Sph + Other	408.	273.	1270.	2200.
Gal + Cpy + Other	1820.	306.	653.	9.
Gal + All Other	7160.	909.	1290.	5510.

Appendix D

RAW SIEVE SIZE AND PARTICLE SIZE DATA

TABLE 1

SIEVE SIZE ANALYSES FOR THE FOUR STALL LAKE END PRODUCTS.

(Retained Weight)

SAMPLE.	Mesh Numbers (and Screen Opening Sizes)						
	+48 (295um)	+65 (208um)	+100 (147um)	+150 (104um)	+200 (74um)	+325 (43um)	-325
1. Feed	0.73	1.23	3.88	7.49	10.5	18.5	57.7
2. Cu-Conc.	1.09	1.07	1.98	4.18	9.60	16.0	66.1
3. Zn-Conc.	0.09	0.37	1.47	3.35	6.23	17.7	70.8
4. Tailings	0.80	1.50	4.54	8.37	10.4	17.0	57.4

TABLE 2

HOST PARTICLE SIZE DISTRIBUTIONS OF CHALCOPYRITE AND SPHALERITE IN THE FOUR STALL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	CHALCOPYRITE Frequency (%)				SPHALERITE Frequency (%)			
	Feed	Cu-Conc	Zn-Conc	Tail	Feed	Cu-Conc	Zn-Conc	Tail
-3.4	2.42	0.50	0.27	0.19	2.91	1.71	0.32	0.06
-4.7	4.77	1.29	0.29	1.46	5.26	2.96	0.85	0.75
-6.7	7.67	2.71	0.26	0.82	8.85	5.81	1.76	1.11
-9.5	12.0	5.08	1.13	1.67	12.6	7.53	3.40	1.90
-13.	15.9	8.06	1.42	1.22	14.9	13.9	7.13	1.95
-19.	19.1	12.5	2.36	1.51	15.4	18.8	12.2	3.71
-27.	15.4	18.4	9.33	3.95	22.4	16.5	18.5	4.71
-38.	13.1	15.8	10.6	6.71	13.7	15.8	23.1	9.81
-53.	7.08	21.3	15.8	14.6	3.90	13.7	21.1	15.4
-75.	2.44	7.07	18.9	0.91	----	2.79	9.13	14.1
-106.	----	7.28	39.6	1.93	----	0.44	1.65	0.90
-147.	----	----	0.06	----	----	----	0.93	13.5
+147.	----	----	----	50.4	----	----	----	32.0

TABLE 3

HOST PARTICLE SIZE DISTRIBUTIONS OF GALENA AND PYRITE IN THE FOUR STALL LAKE END PRODUCTS.

HOST PARTICLE DIAMETER (um)	GALENA Frequency (%)				PYRITE Frequency (%)			
	Feed	Cu-Conc	Zn-Conc	Tail	Feed	Cu-Conc	Zn-Conc	Tail
-3.4	2.71	1.68	1.42	1.13	1.02	0.76	0.27	0.02
-4.7	3.17	1.79	2.49	2.08	2.55	1.97	0.57	0.63
-6.7	4.26	2.22	4.54	1.50	5.09	4.19	0.52	1.34
-9.5	3.96	7.87	6.84	4.17	8.72	7.78	2.85	2.44
-13.	3.19	0.00	14.7	6.11	12.7	12.0	5.73	4.49
-19.	5.84	8.79	8.84	4.09	16.5	19.4	15.5	7.45
-27.	11.5	31.8	11.9	7.37	20.1	29.9	27.1	12.5
-38.	12.8	30.9	12.5	16.5	18.2	16.4	36.4	16.7
-53.	52.5	1.41	2.85	16.1	9.05	7.63	10.9	23.9
-75.	0.08	0.05	33.1	5.40	4.23	0.07	0.16	18.2
-106.	----	13.5	0.79	35.4	1.83	----	----	8.08
-147.	----	----	----	0.11	----	----	----	3.34
+147.	----	----	----	----	----	----	----	0.87

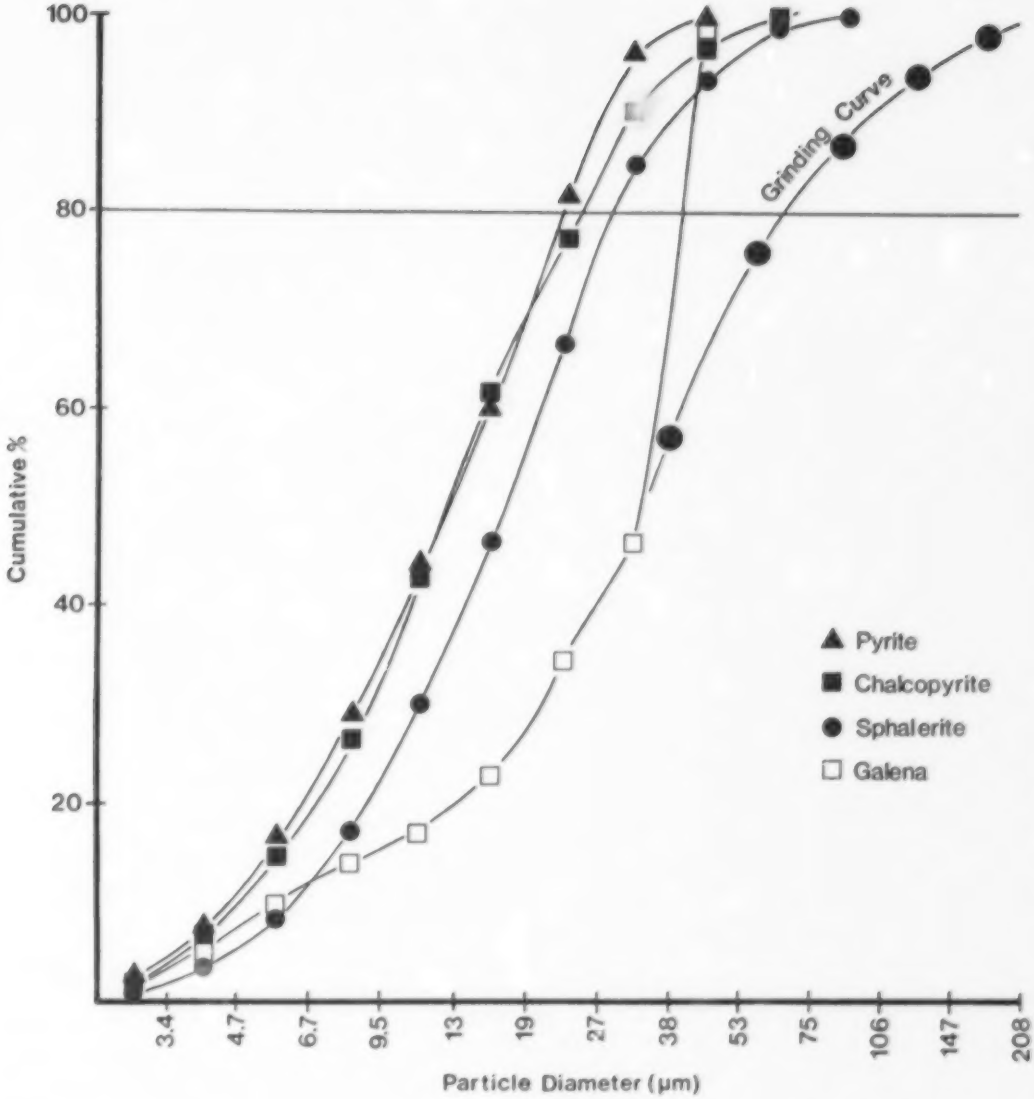

FIGURE 1.
THE HOST PARTICLE SIZE DISTRIBUTIONS OF PYRITE, CHALCOPYRITE, SPHALERITE AND GALENA, AND THE GRINDING CURVE IN THE STALL LAKE FLOTATION FEED.